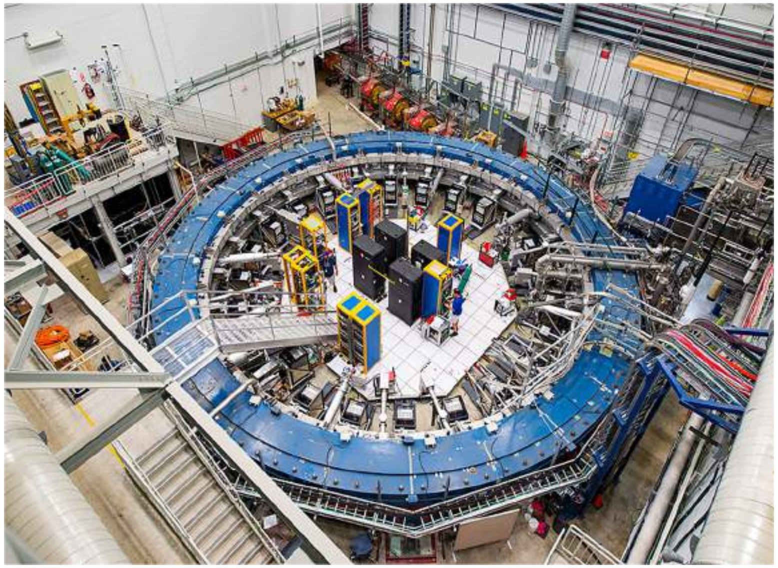
Muon g-2 and $\Delta\alpha$ connection

Keshavarzi, Marciano, Passera and Sirlin

Phys. Rev. D 102 (2020) 033002



Alex Keshavarzi
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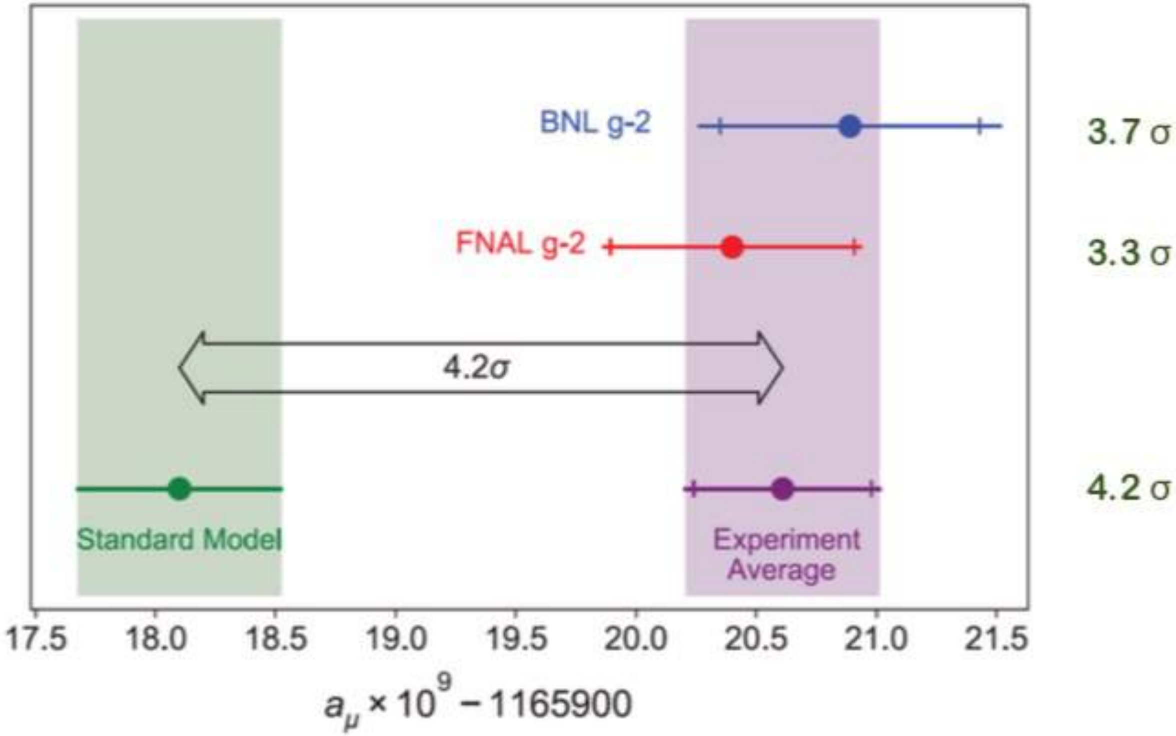
TAU21
29th September 2021

The University of Manchester

Muon g-2: FNAL confirms BNL



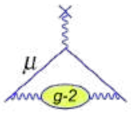
$a_\mu^{EXP} = (116592089 \pm 63) \times 10^{-11}$ [0.54ppm] BNL E821

$a_\mu^{EXP} = (116592040 \pm 54) \times 10^{-11}$ [0.46ppm] FNAL E989 Run 1

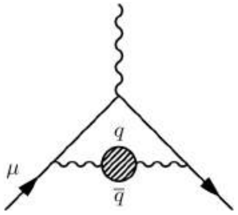
$a_\mu^{EXP} = (116592061 \pm 41) \times 10^{-11}$ [0.35ppm] WA

Muon g-2 in the SM: HVP

$$\Delta a_\mu = 279(76)\times 10^{-11} \rightarrow 2.39(0.65)\ \text{ppm}$$



- Hadronic Vacuum Polarisation - hadronic blob coupled to 2 photons.
- Two-point function - in principle, much easier than HLbL.
- Most precisely calculated from $e^+e^- \rightarrow$ hadrons cross section data.



Lattice (error ~ 1.6 ppm of a_μ^{SM})

- Uncertainties dominated by finite volume, discretisation and isospin breaking systematics.

Data-driven (error ~ 0.3 ppm of a_μ^{SM})

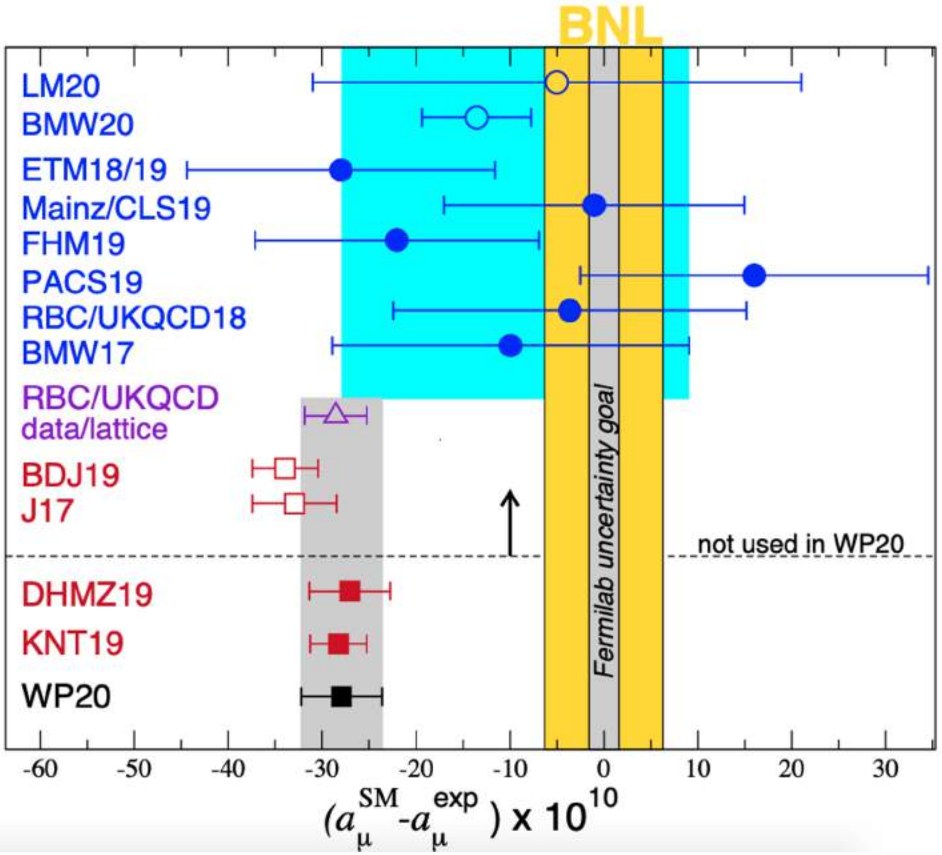
- Cross section data consistently combined and input into dispersion integral:

$$a_\mu^{\text{LO HVP}} = \frac{1}{4\pi^3}\int_{s_{th}}^{\infty} ds\, K(s)\,\sigma_{\text{had}}(s)$$

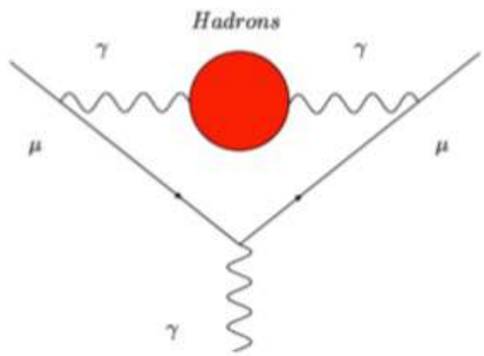
- Several groups have achieved this.

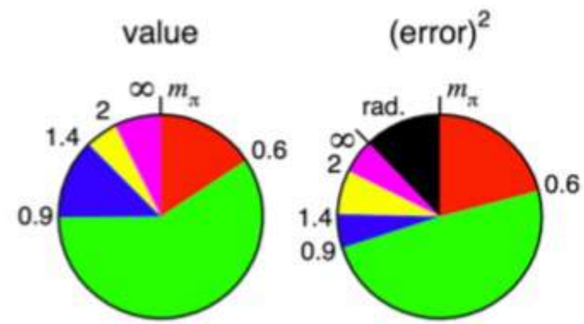
Recommended Muon g-2 TI value from data-driven result:

$$a_\mu^{\text{HVP}} = 6845(40)\times 10^{-11}$$



The LO hadronic contribution





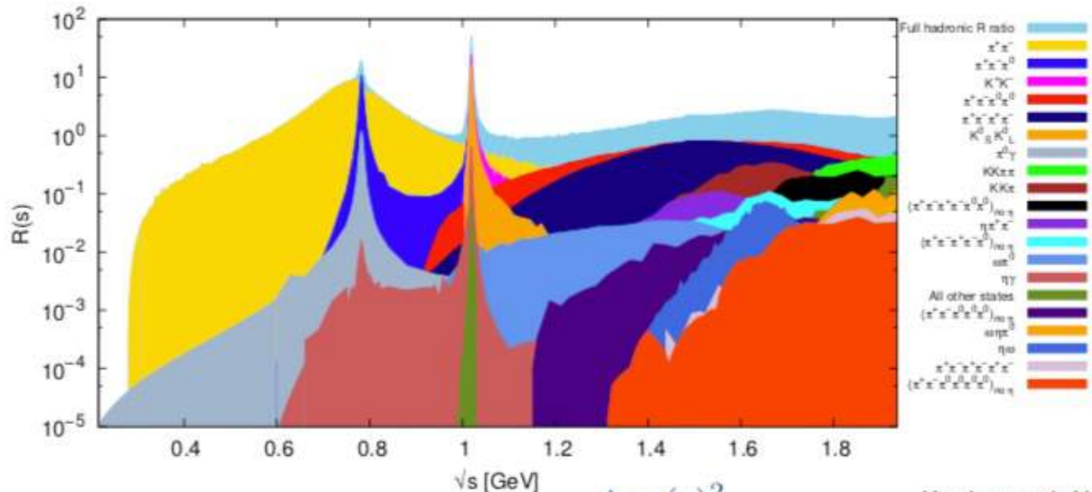
Keshavarzi, Nomura, Teubner 2018

$$a_\mu^{\rm HLO} = \frac{1}{4\pi^3}\int_{m_\pi^2}^{\infty} ds\, K(s)\, \sigma^{(0)}_{\rm had}(s) \qquad K(s) = \int_0^1 dx \frac{x^2\,(1-x)}{x^2 + (1-x)\,(s/m_\mu^2)}$$

$a_\mu^{\rm HLO}$ = 6895 (33) x 10^{-11}	F. Jegerlehner, arXiv:1711.06089
= 6939 (40) x 10^{-11}	Davier, Hoecker, Malaescu, Zhang, arXiv:1908.00921
= 6928 (24) x 10^{-11}	Keshavarzi, Nomura, Teubner, arXiv:1911.00367
= 6931 (40) x 10^{-11} (0.6%)	WP20 value

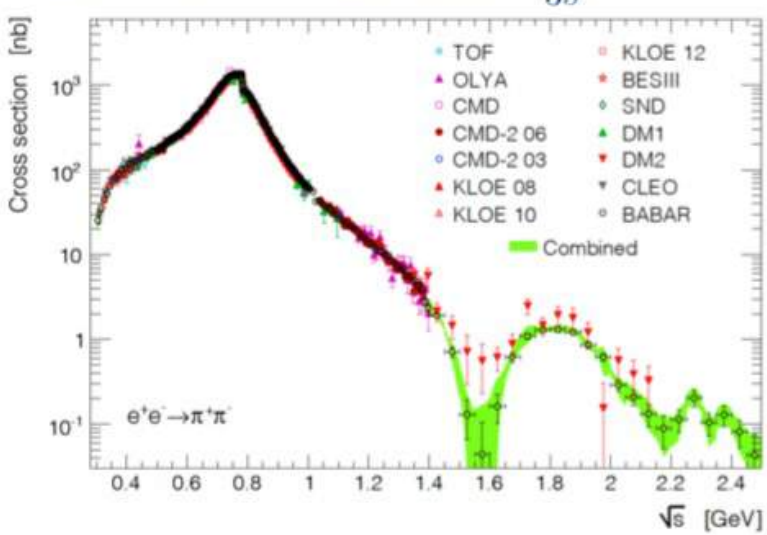
- **WP20 value obtained merging conservatively DHMZ + KNT + constraints from CHHKS**
  Colangelo, Hoferichter, Hoid, Kubis, Stoffer 2018-19
- **Radiative Corrections to σ(s) are crucial.** S. Actis et al, Eur. Phys. J. C66 (2010) 585

Low energy hadronic cross section



$$R(s) = \sigma(e^+e^- \to \text{hadrons}) / \frac{4\pi\alpha(s)^2}{3s}$$

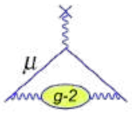
Keshavarzi, Nomura Teubner
PRD 2018



Davier, Hoecker, Malaescu, Zhang
EPJC 2020

Muon g-2: the discrepancy

$\Delta a_\mu = 279(76) \times 10^{-11} \to 2.39(0.65)$ ppm



- Comparing the SM prediction with the measured muon g-2 value:

$a_\mu^{EXP} = 116592061\ (41) \times 10^{-11}$ — BNL+FNAL

$a_\mu^{SM} = 116591810\ (43) \times 10^{-11}$ — WP20

$\Delta a_\mu = a_\mu^{EXP} - a_\mu^{SM} = 251\ (59) \times 10^{-11}$ — 4.2 σ

If BMW 2021 HLO instead of WP20, EXP & SM differ only by 1.6σ

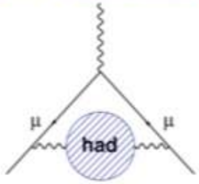
- Is Δa_μ due to new physics beyond the SM? Could be due to:
  - NP at the weak scale and weakly coupled to SM particles
  - NP very heavy and strongly coupled to SM particles
  - NP very light ($\Lambda \lesssim 1$ GeV) and feebly coupled to SM particles

Hadronic cross section data

Experimentally measured hadronic cross section:

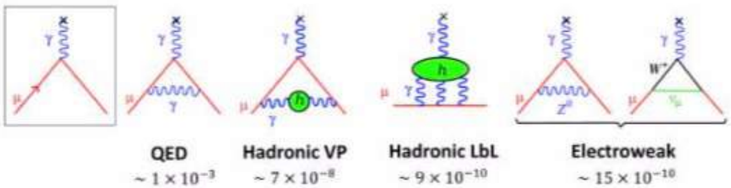
σ_{had}

Muon g-2: hadronic vacuum polarisation contribution



$$a_\mu^{\text{had, VP}} = \frac{1}{4\pi^3}\int_{m_\pi}^{\infty} ds\ \sigma_{\text{had}}(s)\ K(s)$$

… sum with other SM contributions…



→ Determines a_μ^{SM} and $\Delta a_\mu = 3.7\sigma$

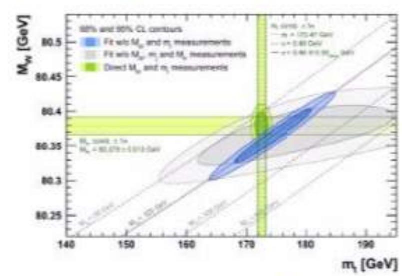
Increase cross section so that $\Delta a_\mu = 0$?

→ Solves muon g-2 discrepancy

Running QED coupling: hadronic contribution to running

$$\Delta\alpha_{\text{had}}^{(5)}(q^2) = \frac{q^2}{4\pi\alpha^2}\int_{m_\pi}^{\infty} ds\ \sigma_{\text{had}}(s)\frac{q^2}{(q^2 - s)}$$

… evaluate at $q^2 = M_Z^2$ and input into **global EW fit**…



→ Predicts $M_W, M_H, \sin^2\theta_{eff}^{lep}$ and more…

Increase cross section so that $\Delta a_\mu = 0$?

→ What happens to precision EW parameters?

Muon g-2 and $\Delta\alpha$

Marciano, Passera and Sirlin
Phys. Rev. D 78 (2008) 013009

MANCHESTER 1824
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- **Can Δa_μ be due to hypothetical mistakes in the hadronic $\sigma(s)$?**
- **An upward shift of $\sigma(s)$ also induces an increase of $\Delta\alpha_{had}^{(5)}(M_Z)$.**
- **Consider:**

$$a_\mu^{HLO} \rightarrow \quad a = \int_{4m_\pi^2}^{s_u} ds\, f(s)\, \sigma(s), \qquad f(s) = \frac{K(s)}{4\pi^3}, \; s_u < M_Z^2,$$

$$\Delta\alpha_{had}^{(5)} \rightarrow \quad b = \int_{4m_\pi^2}^{s_u} ds\, g(s)\, \sigma(s), \qquad g(s) = \frac{M_Z^2}{(M_Z^2 - s)(4\alpha\pi^2)},$$

and the increase

$$\Delta\sigma(s) = \epsilon\sigma(s)$$

ϵ>0, in the range:

$$\sqrt{s} \in [\sqrt{s_0} - \delta/2, \sqrt{s_0} + \delta/2]$$

Note the very different energy-dependent weighting of the integrands…

Use precise and up-to-date compilation of total hadronic cross section from KNT
Keshavarzi, Nomura and Teubner, Phys.Rev.D 101 (2020) 014029, arXiv:1911.00367

Muon g-2: connection with the SM Higgs

Major update: Higgs discovered, improved EW observables (M_W, $\sin^2\theta$, M_{top}, …), updates to $\sigma(s)$, theory improvements, global fit, …

Using Gfitter

Parameter	Input value	Reference	Fit result	Result w/o input value
M_W (GeV)	80.379(12)	[5]	80.359(3)	80.357(4)(5)
M_H (GeV)	125.10(14)	[5]	125.10(14)	94^{+20+6}_{-18-6}
$\Delta\alpha^{(5)}_{\rm had}(M_Z^2) \times 10^4$	276.1(1.1)	[23]	275.8(1.1)	272.2(3.9)(1.2)
m_t (GeV)	172.9(4)	[5]	173.0(4)	⋯
$\alpha_s(M_Z^2)$	0.1179(10)	[5]	0.1180(7)	⋯
M_Z (GeV)	91.1876(21)	[5]	91.1883(20)	⋯
Γ_Z (GeV)	2.4952(23)	[5]	2.4940(4)	⋯
Γ_W (GeV)	2.085(42)	[5]	2.0903(4)	⋯
$\sigma^0_{\rm had}$ (nb)	41.541(37)	[108]	41.490(4)	⋯
R^0_l	20.767(25)	[108]	20.732(4)	⋯
R^0_c	0.1721(30)	[108]	0.17222(8)	⋯
R^0_b	0.21629(66)	[108]	0.21581(8)	⋯
$\bar{m}_c$ (GeV)	1.27(2)	[5]	1.27(2)	⋯
$\bar{m}_b$ (GeV)	$4.18^{+0.03}_{-0.02}$	[5]	$4.18^{+0.03}_{-0.02}$	⋯
$A^{0,l}_{\rm FB}$	0.0171(10)	[108]	0.01622(7)	⋯
$A^{0,c}_{\rm FB}$	0.0707(35)	[108]	0.0737(2)	⋯
$A^{0,b}_{\rm FB}$	0.0992(16)	[108]	0.1031(2)	⋯
A_ℓ	0.1499(18)	[75,108]	0.1471(3)	⋯
A_c	0.670(27)	[108]	0.6679(2)	⋯
A_b	0.923(20)	[108]	0.93462(7)	⋯
$\sin^2\theta^{\rm lep}_{\rm eff}(Q_{\rm FB})$	0.2324(12)	[108]	0.23152(4)	0.23152(4)(4)
$\sin^2\theta^{\rm lep}_{\rm eff}$(Had Coll)	0.23140(23)	[100]	0.23152(4)	0.23152(4)(4)

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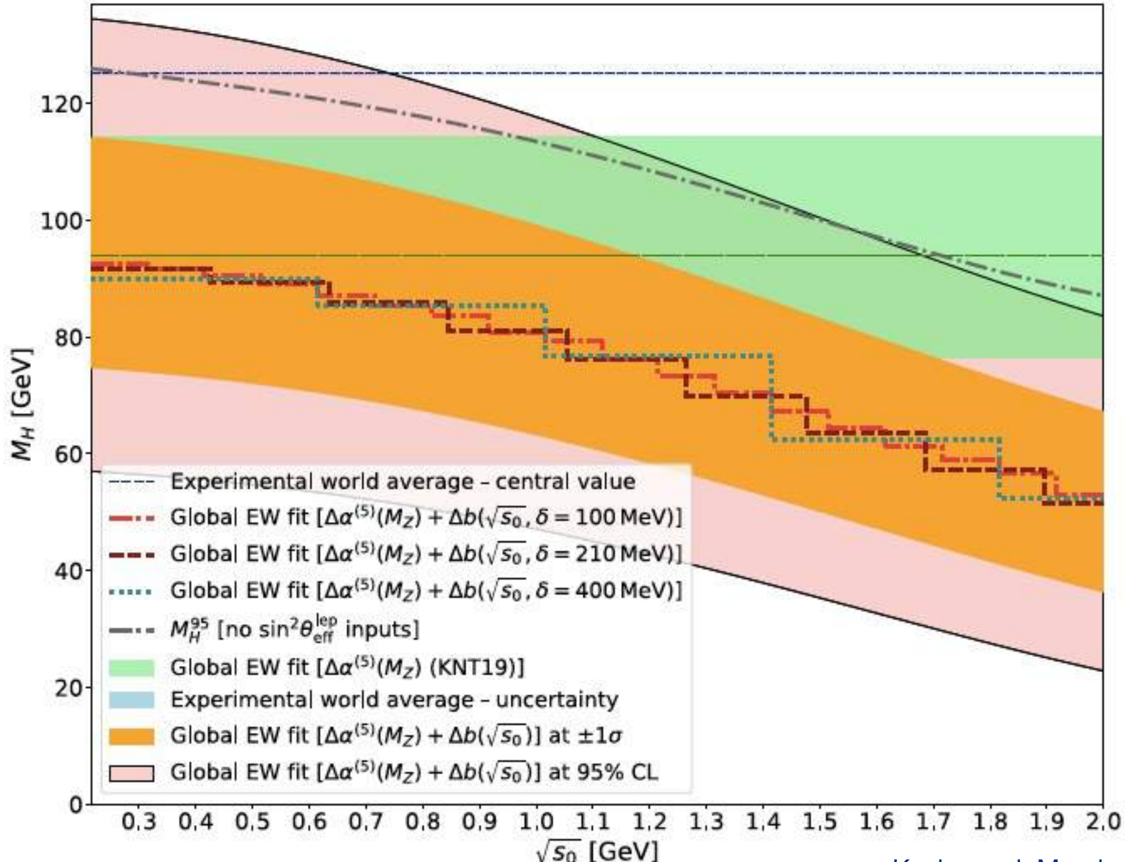
Muon g-2: connection with the SM Higgs



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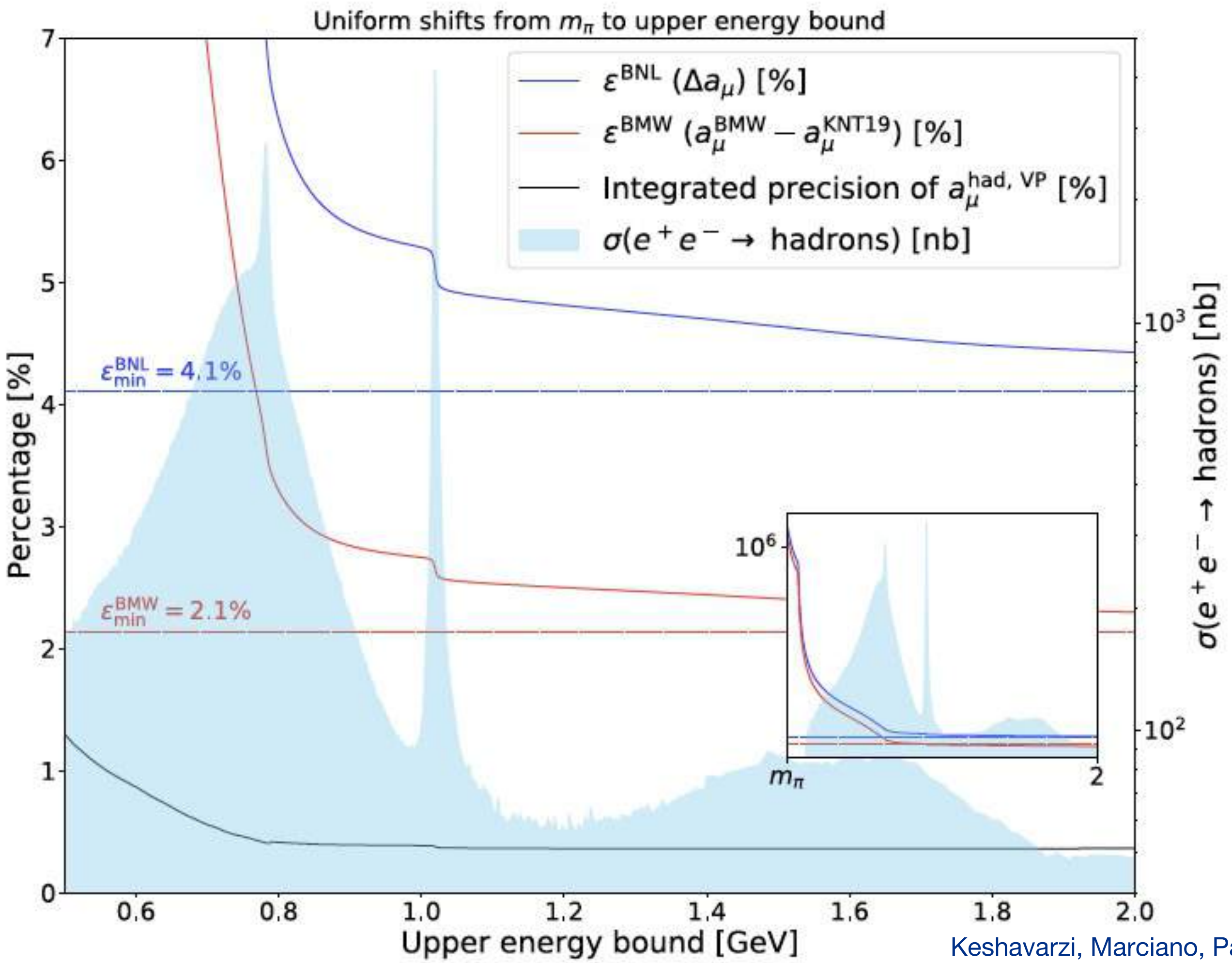
Shifts $\Delta\sigma(s)$ to fix Δa_μ are possible, but conflict with the EW fit if they occur above ~1 GeV

How large are the required shifts?



Keshavarzi, Marciano, Passera and Sirlin
Phys. Rev. D 102 (2020) 033002

Shifts below ~1 GeV conflict with the quoted exp. precision of σ(s)

$a_\mu \leftrightarrow \Delta\alpha$: recent related literature

- Crivellin, Hoferichter, Manzari and Montull, "Hadronic vacuum polarization: $(g\text{-}2)_\mu$ versus global electroweak fits," arXiv:2003.04886.

- Eduardo de Rafael, "On Constraints Between $\Delta\alpha_{had}(M_Z^2)$ and $(g_\mu\text{-}2)_{HVP}$," arXiv:2006.13880.

- Malaescu and Schott, "Impact of correlations between a_μ and α_{QED} on the EW fit," arXiv:2008.08107.

- Colangelo, Hoferichter and Stoffer, "Constraints on the two-pion contribution to hadronic vacuum polarization," arXiv:2010.07943.

Conclusions

- Fermilab's Muon g-2 Experiment has confirmed BNL's result: the discrepancy between experiment and SM increases to 4.2σ.
- The BMWc lattice QCD result weakens the exp-SM discrepancy. It must be confirmed or refuted by other lattice calculations.
- Both the hadronic contributions to the muon g-2 and the running QED coupling depend on the measured hadronic cross section.
- This connection between g-2 and $\Delta\alpha$ allows the impact of the muon g-2 discrepancy on the EW fit to be explored.
- Increases to the hadronic cross section to solve muon g-2 discrepancy affect the predictions of EW precision observables.
- This study excludes shifts to hadronic cross section above 0.7 GeV to bridge muon g-2 discrepancy.
- However, the required shifts to the hadronic cross section below 0.7 GeV are large and unlikely.

Backups

Magnetic moments

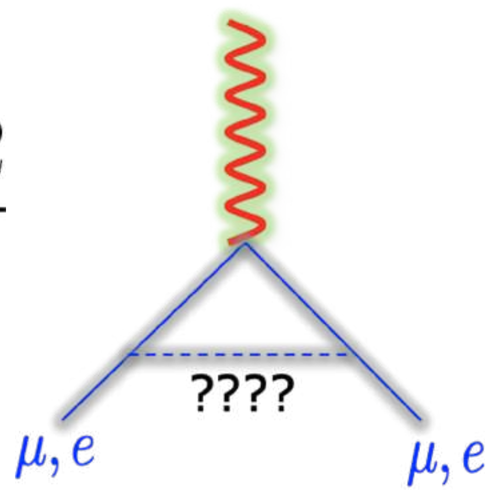
The muon has an intrinsic magnetic moment that is coupled to its spin via the gyromagnetic ratio *g*:

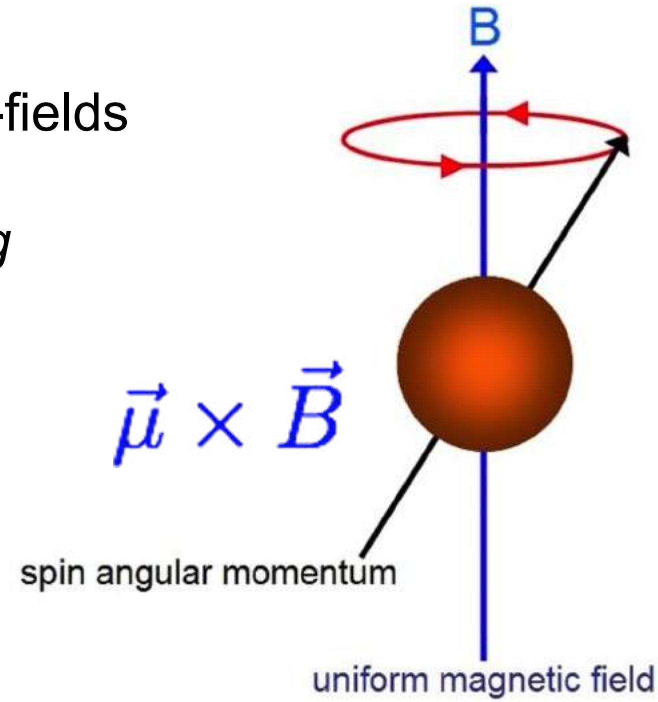
$$\vec{\mu} = g\frac{e}{2m_\mu}\vec{S}$$

Magnetic moment (spin) interacts with external B-fields

Makes spin precess at frequency determined by *g*

$$a_\mu = \frac{g-2}{2}$$





Muon g-2 Theory

arXiv.org > hep-ph > arXiv:2006.04822

High Energy Physics – Phenomenology

[Submitted on 8 Jun 2020]

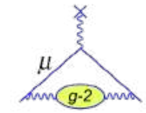
The anomalous magnetic moment of the muon in the Standard Model

T. Aoyama, N. Asmussen, M. Benayoun, J. Bijnens, T. Blum, M. Bruno, I. Caprini, C. M. Carloni Calame, M. Cè, G. Colangelo, F. Curciarello, H. Czyż, I. Danilkin, M. Davier, C. T. H. Davies, M. Della Morte, S. I. Eidelman, A. X. El-Khadra, A. Gérardin, D. Giusti, M. Golterman, Steven Gottlieb, V. Gülpers, F. Hagelstein, M. Hayakawa, G. Herdoíza, D. W. Hertzog, A. Hoecker, M. Hoferichter, B.-L. Hoid, R. J. Hudspith, F. Ignatov, T. Izubuchi, F. Jegerlehner, L. Jin, A. Keshavarzi, T. Kinoshita, B. Kubis, A. Kupich, A. Kupść, L. Laub, C. Lehner, L. Lellouch, I. Logashenko, B. Malaescu, K. Maltman, M. K. Marinković, P. Masjuan, A. S. Meyer, H. B. Meyer, T. Mibe, K. Miura, S. E. Müller, M. Nio, D. Nomura, A. Nyffeler, V. Pascalutsa, M. Passera, E. Perez del Rio, S. Peris, A. Portelli, M. Procura, C. F. Redmer, B. L. Roberts, P. Sánchez-Puertas, S. Serednyakov, B. Shwartz, S. Simula, D. Stöckinger, H. Stöckinger-Kim, P. Stoffer, T. Teubner, R. Van de Water, M. Vanderhaeghen, G. Venanzoni, G. von Hippel, H. Wittig, Z. Zhang, M. N. Achasov, A. Bashir, N. Cardoso, B. Chakraborty, E.-H. Chao, J. Charles, A. Crivellin, O. Deineka, A. Denig, C. DeTar, C. A. Dominguez, A. E. Dorokhov, V. P. Druzhinin, G. Eichmann, M. Fael, C. S. Fischer, E. Gámiz, Z. Gelzer, J. R. Green, S. Guellati-Khelifa, D. Hatton, N. Hermansson-Truedsson et al. (32 additional authors not shown)

The Muon g-2 Theory Initiative

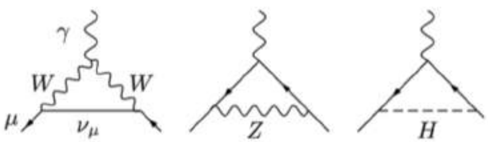
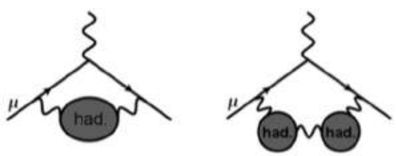
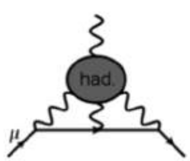
Muon g-2 in the SM

$$\Delta a_\mu = 279(76) \times 10^{-11} \rightarrow 2.39(0.65)\ \text{ppm}$$



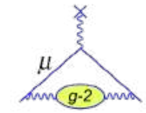
- a_μ arises due to quantum corrections / higher order interactions / loop contributions
- All SM particles contribute → Calculate and sum all sectors of the SM:

$$a_\mu^{\text{SM}} = a_\mu^{\text{QED}} + a_\mu^{\text{EW}} + a_\mu^{\text{HVP}} + a_\mu^{\text{HLbL}}$$

			a_μ^{SM} portion	δa_μ^{SM} portion
QED		Perturbative (Known to five-loop)	$\sim 99.99\%$	~0.001%
EW		Perturbative (Known to two-loop)	~ 1 ppm	~0.2%
HVP		Non-perturbative (Data-driven & lattice)	~ 59 ppm	**~84%**
HLbL		Non-perturbative (Data-driven & lattice)	~ 1 ppm	**~16%**

Muon g-2 in the SM: QED

$\Delta a_\mu = 279(76) \times 10^{-11} \rightarrow 2.39(0.65)$ ppm



$a_\mu^{QED} = (1/2)(\alpha/\pi)$ Schwinger 1948

$+ \ 0.765857426\ (16)\ (\alpha/\pi)^2$

Sommerfield; Petermann; Suura&Wichmann '57; Elend '66; MP '04

$+ \ 24.05050988\ (28)\ (\alpha/\pi)^3$

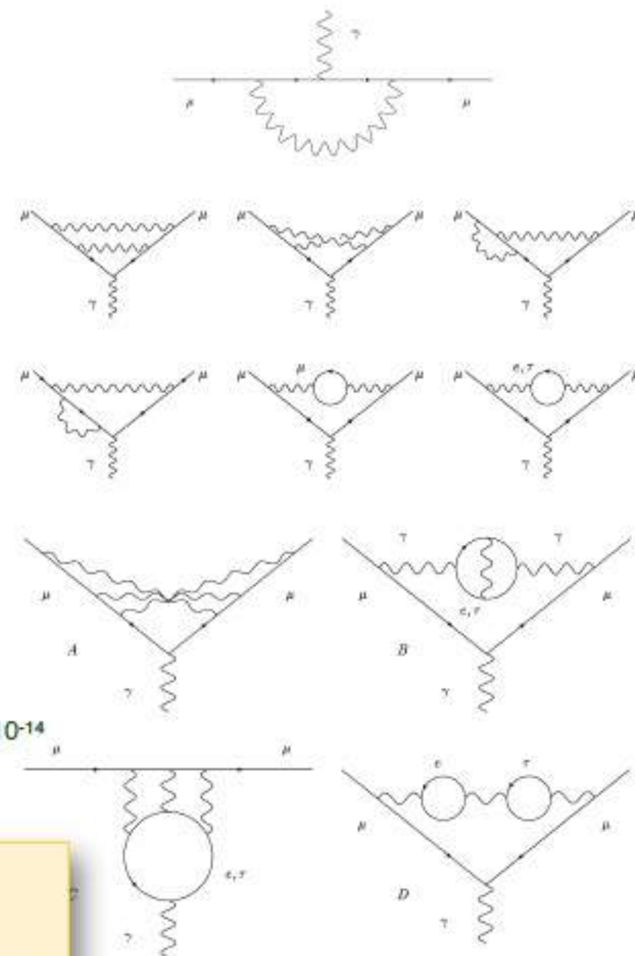
Remiddi, Laporta, Barbieri … ; Czarnecki, Skrzypek '99; MP '04;
Friot, Greynat & de Rafael '05, Ananthanarayan, Friot, Ghosh 2020

$+ \ 130.8780\ (60)\ (\alpha/\pi)^4$

Kinoshita & Lindquist '81, … , Kinoshita & Nio '04, '05;
Aoyama, Hayakawa, Kinoshita & Nio, 2007, Kinoshita et al. 2012 & 2015;
Steinhauser et al. 2013, 2015 & 2016 (all electron & τ loops, analytic);
Laporta, PLB 2017 (mass independent term) COMPLETED²!

$+ \ 750.86\ (88)\ (\alpha/\pi)^5$ COMPLETED!

Kinoshita et al. '90, Yelkhovsky, Milstein, Starshenko, Laporta,…
Aoyama, Hayakawa, Kinoshita, Nio 2012, 2015, 2017 & 2019.
Volkov 1909.08015: $A_1^{(10)}$[no lept loops] at variance, but negligible $\delta a_\mu \sim 6\times10^{-14}$



Adding up, we get:

$a_\mu^{QED} = 116584718.931\ (19)(100)(23) \times 10^{-11}$

mainly from 4-loop coeff. unc. 6-loop from α(Cs)

α = 1/137.035999046(27) [0.2ppb] Parker et al 2018 WP20 value

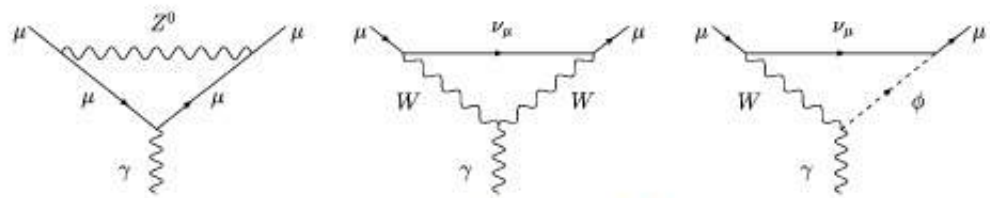
Shift down in $a_\mu^{QED} \sim 1.4 \times 10^{-12}$ with new LKB Paris α(Rb) value (Morel et al 2020)

M Passera IISER Pune June 16 2021 8

Muon g-2 in the SM: EW

$$\Delta a_\mu = 279(76) \times 10^{-11} \rightarrow 2.39(0.65)\ \text{ppm}$$

- **One-loop term:**



$$a_\mu^{\rm EW}(\text{1-loop}) = \frac{5G_\mu m_\mu^2}{24\sqrt{2}\pi^2}\left[1+\frac{1}{5}\left(1-4\sin^2\theta_W\right)^2 + O\left(\frac{m_\mu^2}{M_{Z,W,H}^2}\right)\right] \approx 195\times 10^{-11}$$

1972: Jackiv, Weinberg; Bars, Yoshimura; Altarelli, Cabibbo, Maiani; Bardeen, Gastmans, Lautrup; Fujikawa, Lee, Sanda;
Studenikin et al. '80s

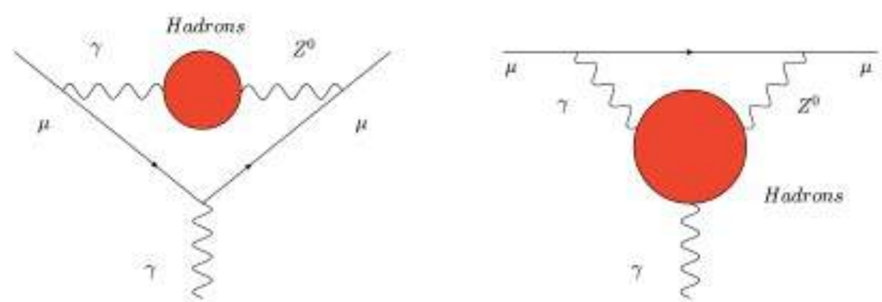
- **One-loop plus higher-order terms:**

$a_\mu^{\rm EW} = 153.6\ (1.0) \times 10^{-11}$

Kukhto et al. '92; Czarnecki, Krause, Marciano '95; Knecht, Peris, Perrottet, de Rafael '02; Czarnecki, Marciano and Vainshtein '02; Degrassi and Giudice '98; Heinemeyer, Stockinger, Weiglein '04; Gribouk and Czarnecki '05; Vainshtein '03; Gnendiger, Stockinger, Stockinger-Kim 2013, Ishikawa, Nakazawa, Yasui, 2019.

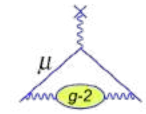
Hadronic loop uncertainties (and 3-loop nonleading logs).

WP20 value

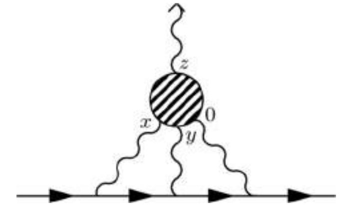


Muon g-2 in the SM: HLbL

$\Delta a_\mu = 279(76) \times 10^{-11} \rightarrow 2.39(0.65)$ ppm



- HLbL scattering - hadronic blob coupled to 3 off-shell/1 on-shell photon.
- Four point function - notoriously difficult to calculate.
- Previously only calculated from models with large systematics.

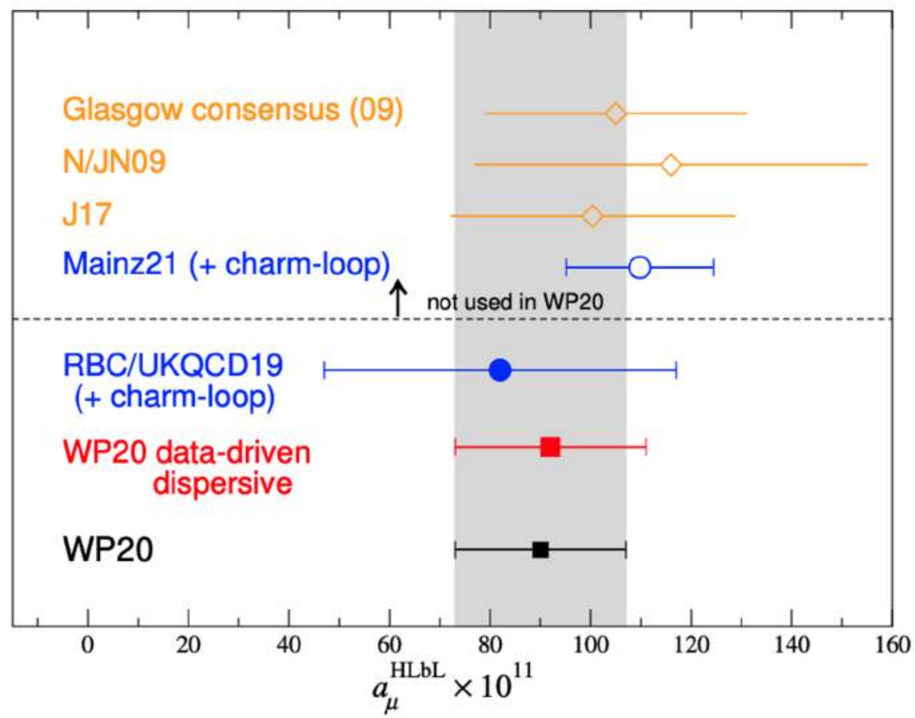


Data-driven (error ~ 0.2 ppm of $a_\mu^{\rm SM}$)

- Model-independent dispersive evaluation, using data (e.g. π, η, η' TFFs) as input for hadronic insertions.

Lattice (error ~ 0.3 ppm of $a_\mu^{\rm SM}$)

- Model-independent evaluation, computed on discretized Euclidean spacetime (lattice) in finite volume.



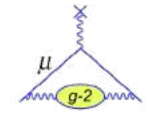
Recommended Muon g-2 TI result (before Mainz):

$$a_\mu^{\rm HLbL} = 92(18) \times 10^{-11}$$

Improved, but still evolving.
Still systematics dominated
(goal < 10% uncertainty)

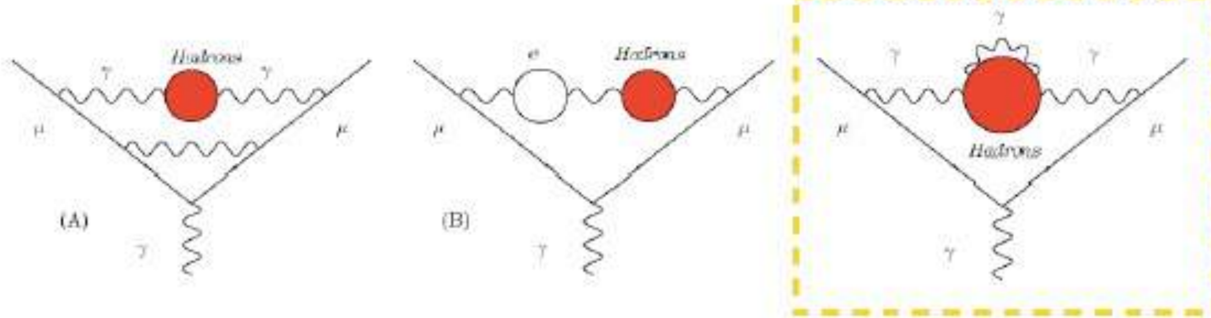
Muon g-2: NLO HVP

$$\Delta a_\mu = 279(76) \times 10^{-11} \rightarrow 2.39(0.65)\ \text{ppm}$$



- $O(\alpha^3)$ contributions of diagrams containing HVP insertions:

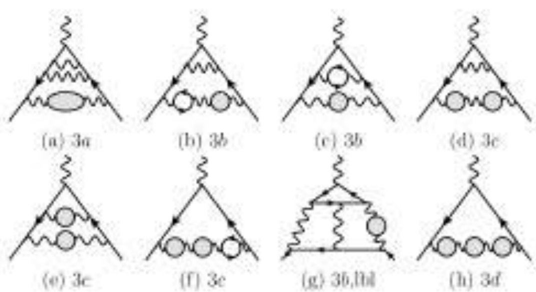
Already included in a_μ^{HLO}



$a_\mu^{HNLO}(vp) = -98.3\ (7) \times 10^{-11}$

Krause '96; Keshavarzi, Nomura, Teubner 2019; WP20.

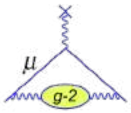
- $O(\alpha^4)$ contributions of diagrams containing HVP insertions:



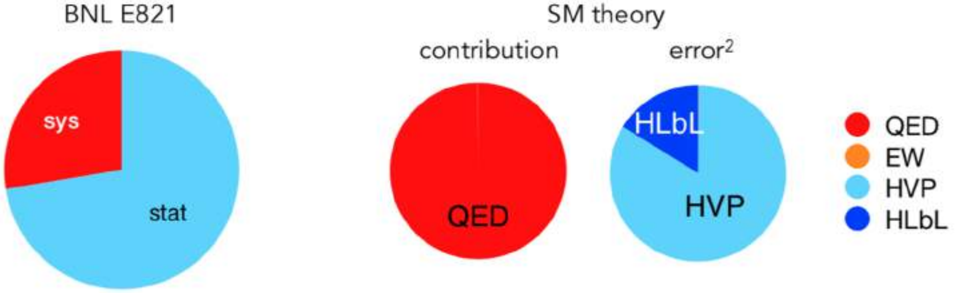
$a_\mu^{HNNLO}(vp) = 12.4\ (1) \times 10^{-11}$

Kurz, Liu, Marquard, Steinhauser 2014

Muon g-2 in the SM and Outlook



Contribution	Value $\times 10^{11}$
Experiment (E821)	116 592 089(63)
HVP LO (e^+e^-)	6931(40)
HVP NLO (e^+e^-)	−98.3(7)
HVP NNLO (e^+e^-)	12.4(1)
HVP LO (lattice, *udsc*)	7116(184)
HLbL (phenomenology)	92(19)
HLbL NLO (phenomenology)	2(1)
HLbL (lattice, *uds*)	79(35)
HLbL (phenomenology + lattice)	90(17)
QED	116 584 718.931(104)
Electroweak	153.6(1.0)
HVP (e^+e^-, LO + NLO + NNLO)	6845(40)
HLbL (phenomenology + lattice + NLO)	92(18)
Total SM Value	116 591 810(43)
Difference: $\Delta a_\mu := a_\mu^{\rm exp} - a_\mu^{\rm SM}$	279(76)



$$\Delta a_\mu = 279(76) \times 10^{-11} \to 2.39(0.65)\ \text{ppm}$$

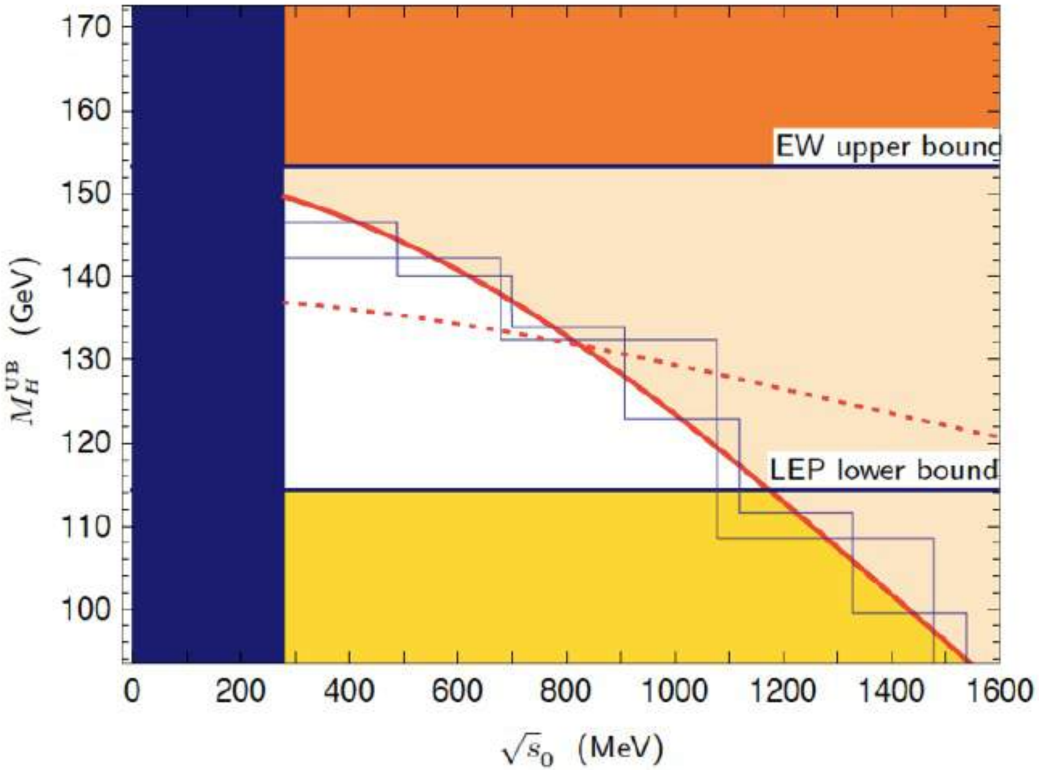
Muon g-2 theory initiative recommended result:

$$a_\mu^{\rm SM} = 116\,591\,810(43) \times 10^{-11}\ (0.37\ \text{ppm})$$

Results in 3.7σ discrepancy when compared to BNL measurement.

Muon g-2: connection with the SM Higgs

How much does the M_H upper bound from the EW fit change when we shift up $\sigma(s)$ by $\Delta\sigma(s)$ [and thus $\Delta\alpha_{had}^{(5)}(M_Z)$] to fix Δa_μ ?

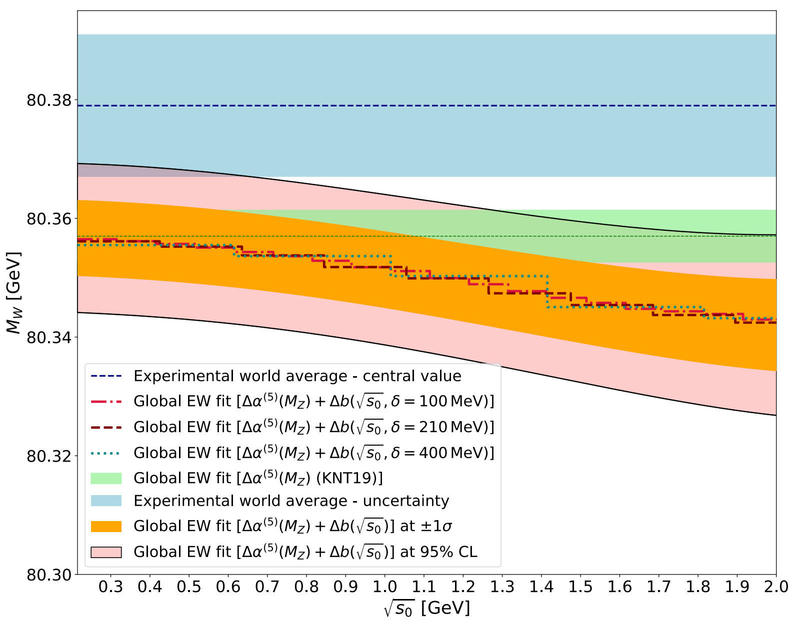


Marciano, MP, Sirlin, PRD 2008

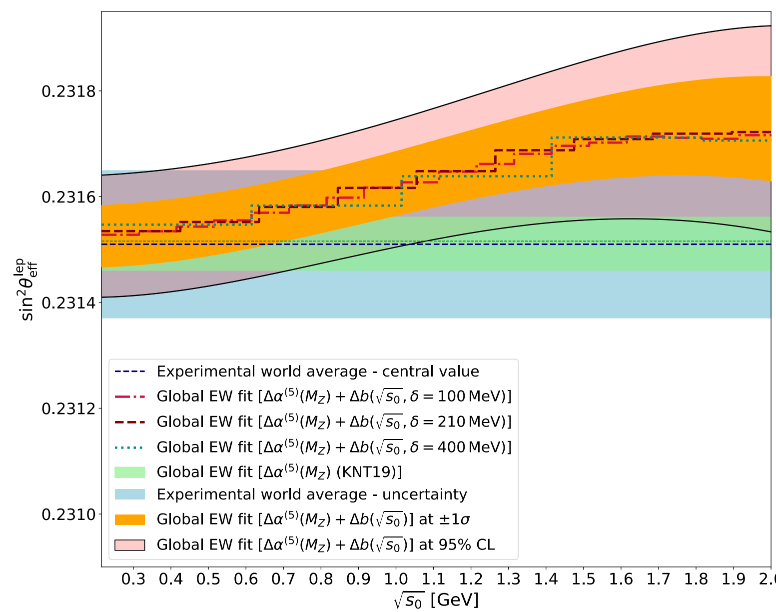
Muon g-2: connection with EW sector

- Shift KNT hadronic cross section in fully energy-dependent (point-like and binned) analysis to account for Δa_μ.
- Input new values of $\Delta\alpha$ into Gfitter to predict EW observables.
- Analysis greatly constrained from precise EW observables measurements and comprehensive hadronic cross section data.

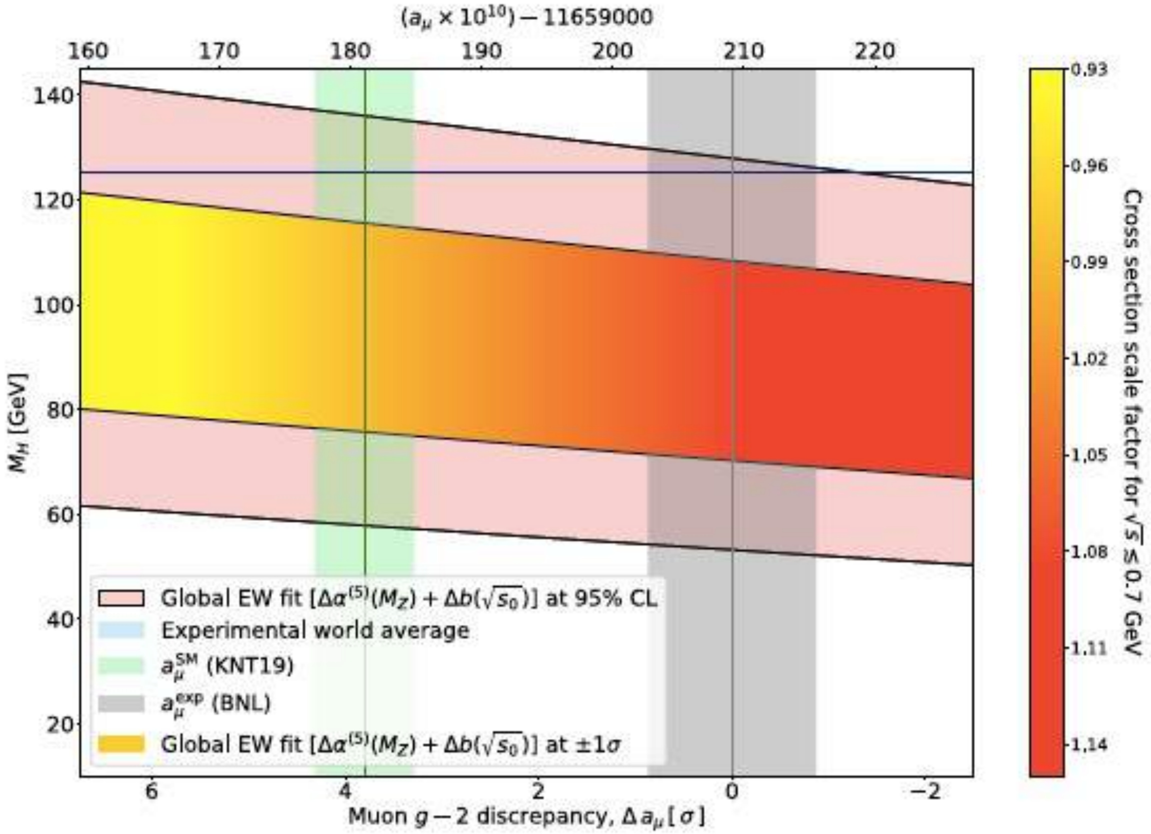
M_W



$\sin^2\theta_{eff}^{lep}$

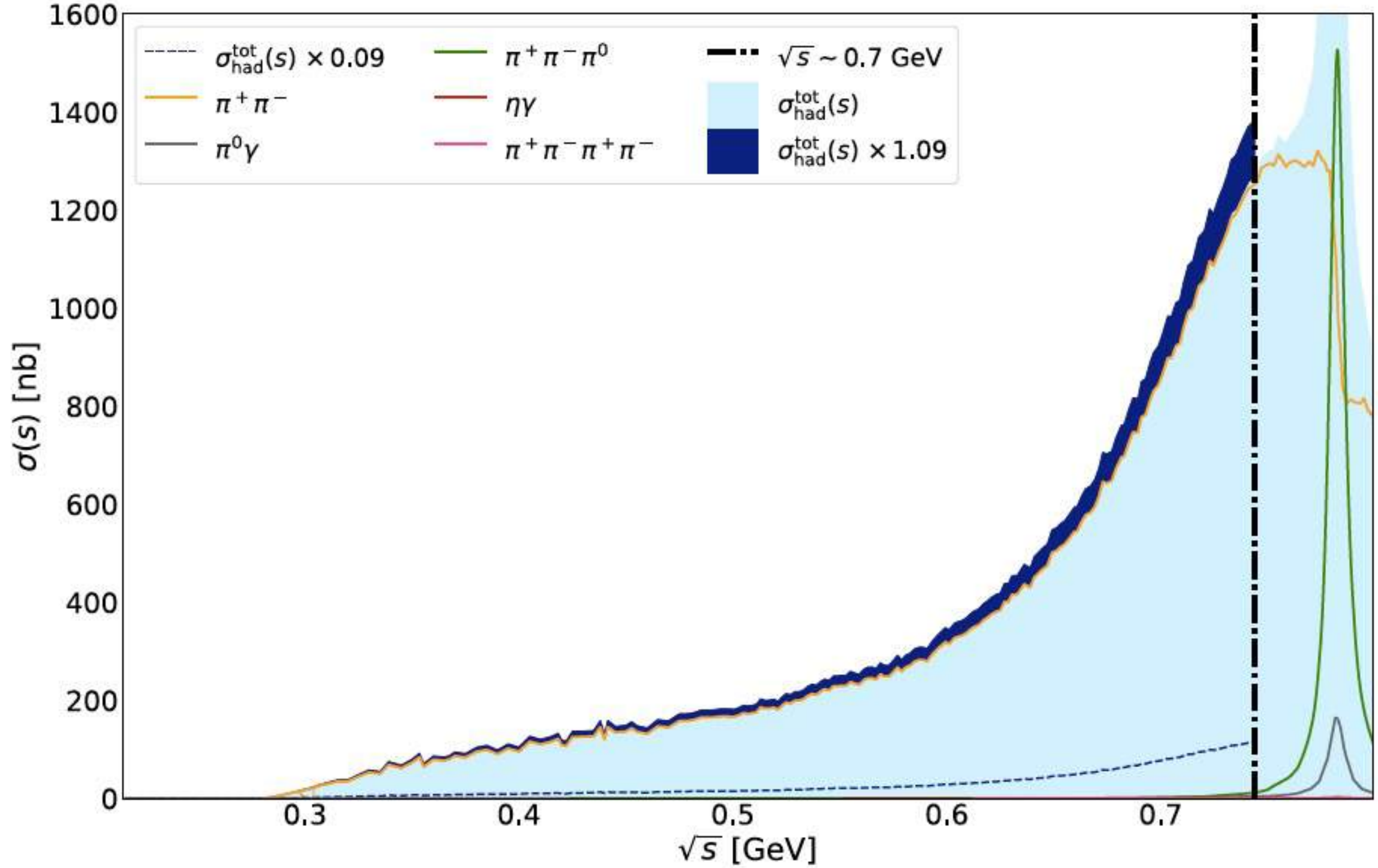


Muon g-2: connection with SM Higgs

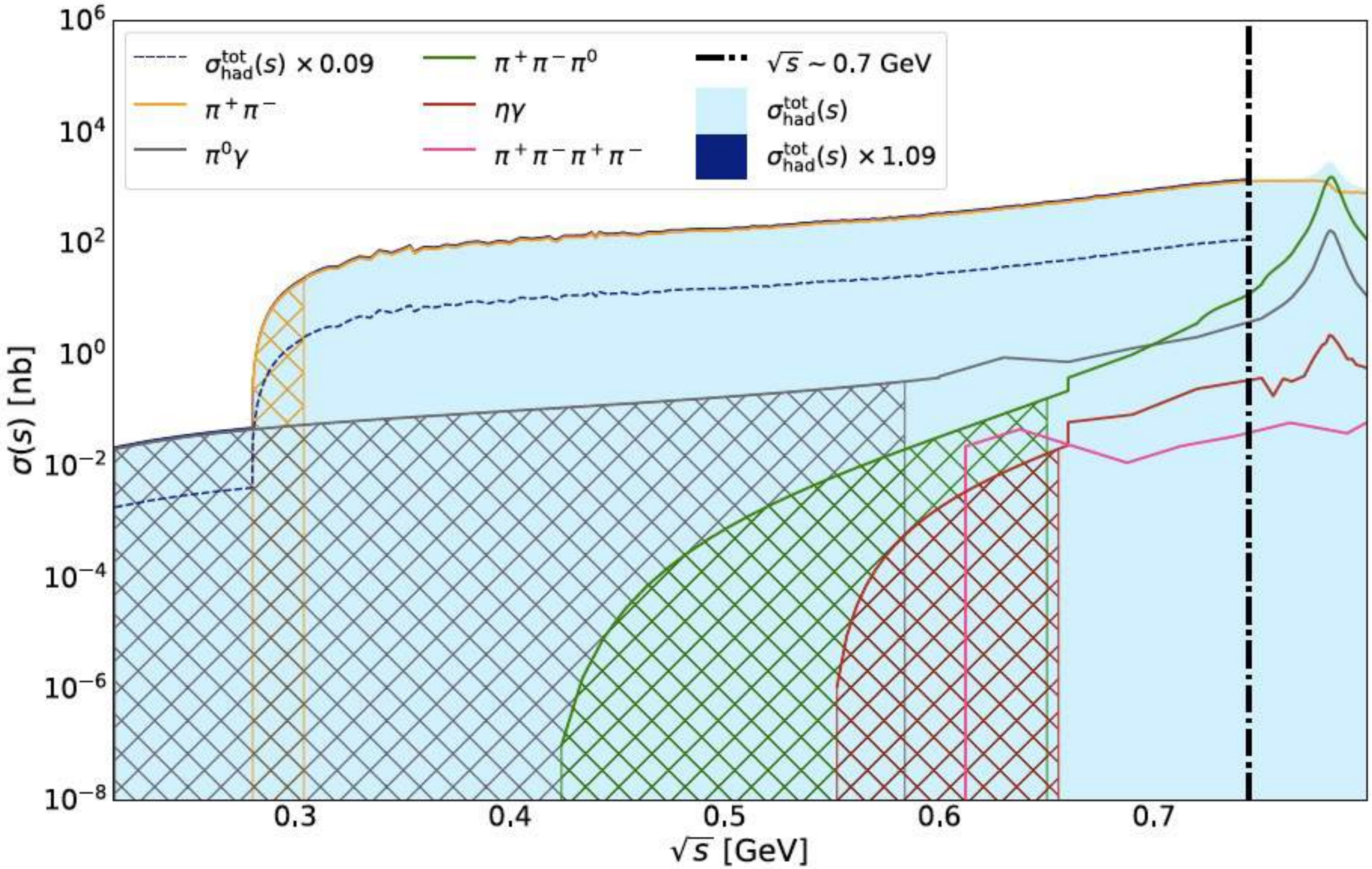


Uniform scaling of σ(s) below ~0.7 GeV? +9% required!

Keshavarzi, Marciano, MP, Sirlin, PRD 2020



Keshavarzi, Marciano, MP, Sirlin, PRD 2020



Keshavarzi, Marciano, MP, Sirlin, PRD 2020

Electron g-2

- The 2008 measurement of the electron g-2 is:

  $a_e^{EXP} = 11596521807.3\ (2.8) \times 10^{-13}$ Hanneke et al, PRL100 (2008) 120801

  vs. old (factor of 15 improvement, 1.8σ difference):

  $a_e^{EXP} = 11596521883\ (42) \times 10^{-13}$ Van Dyck et al, PRL59 (1987) 26

- Equate $a_e^{SM}(\alpha) = a_e^{EXP}$ → "g_e-2" determination of alpha:

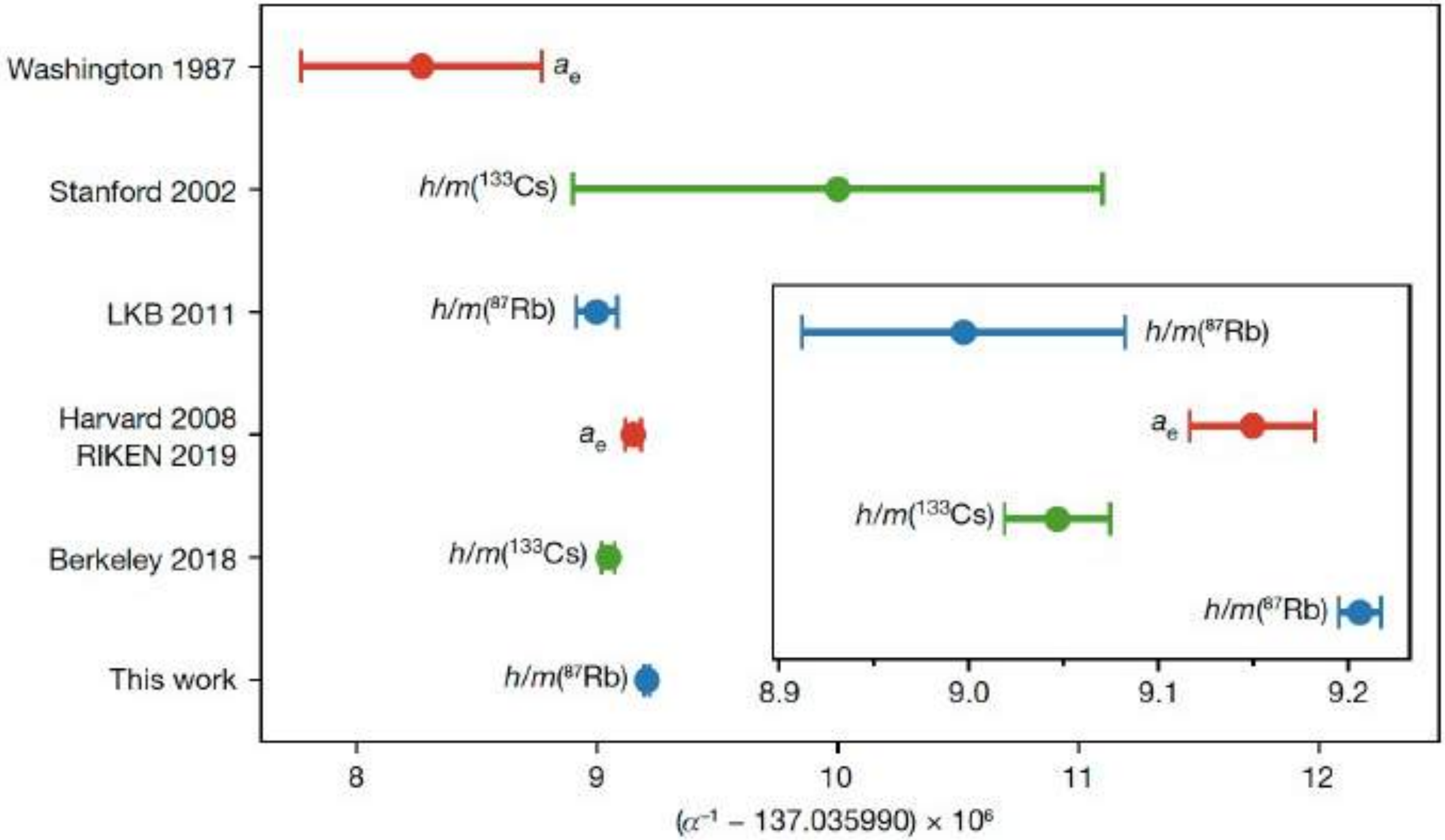
  $\alpha^{-1} = 137.035\,999\,151\ (33)$ [0.24 ppb]

- The best determination of α is obtained via atomic interferometry:

  $\alpha^{-1} = 137.035\,999\,046\ (27)$ [0.20 ppb] Parker et al, Science 360 (2018) 192 (Cs)

  $\alpha^{-1} = 137.035\,999\,206\ (11)$ [0.08 ppb] Morel et al, Nature 588 (2020) 61 (Rb)

  2018→2020: improvement in precision, but 5.4σ difference!



Morel et al, Nature 588 (2020) 61

Electron g-2

- Using the best determinations of α (which differ by 5.4σ!):

  $\alpha = 1/137.035\,999\,046\,(27)$ [Cs 2018]

  $\alpha = 1/137.035\,999\,206\,(11)$ [Rb 2020]

$$a_e^{SM} = 115\,965\,218\,16.16\,(0.11)\,(0.08)\,(2.28) \times 10^{-13} \text{ [Cs18]}$$
$$= 115\,965\,218\,02.64\,(0.11)\,(0.08)\,(0.93) \times 10^{-13} \text{ [Rb20]}$$

δC_5^{qed} δa_e^{had} from $\delta\alpha$

$a_e^{EXP} = 115\,965\,218\,07.3\,(2.8) \times 10^{-13}$ Hanneke et al, PRL 2008

- The (EXP – SM) difference is:

$$\Delta a_e = a_e^{EXP} - a_e^{SM} = -8.9\,(3.6) \times 10^{-13}\ [2.5\sigma] \text{ [Cs18]}$$
$$= +4.7\,(3.0) \times 10^{-13}\ [1.6\sigma] \text{ [Rb20]}$$

QED 5-loop: $a_e^{QED5} = 4.6 \times 10^{-13}$

- NP sensitivity limited only by the experimental errors in α and a_e. May soon play a pivotal role in probing NP in the leptonic sector.

Giudice, Paradisi, MP 2012

Passera IISER Pune June 16 2021

Electron g-2: new physics

- Using α(Rb2020), the sensitivity is $\delta\Delta a_e = 3.0 \times 10^{-13}$, ie ($\times 10^{-13}$):

$$\underbrace{(0.1)_{\text{QED5}}, \quad (0.1)_{\text{HAD}},}_{(0.2)_{\text{TH}}} \quad (0.9)_{\delta\alpha}, \quad (2.8)_{\delta a_e^{\text{EXP}}}$$

- The $(g\text{-}2)_e$ experimental error may soon drop below 10^{-13} → a_e sensitivity below 10^{-13} may soon be reached!

- In a broad class of BSM theories, contributions to a_l scale as

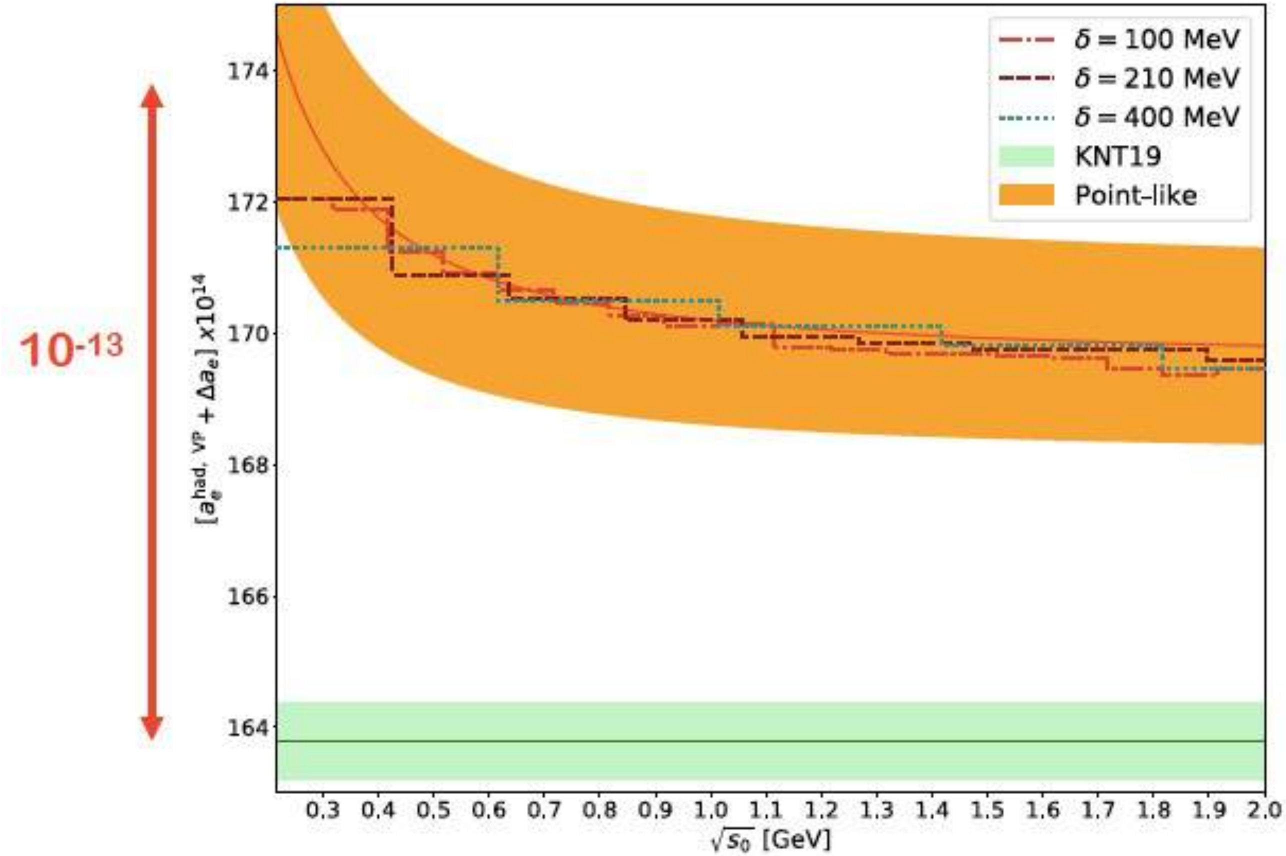
$$\frac{\Delta a_{\ell_i}}{\Delta a_{\ell_j}} = \left(\frac{m_{\ell_i}}{m_{\ell_j}}\right)^2$$

This Naive Scaling leads to:

$$\Delta a_e = \left(\frac{\Delta a_\mu}{3 \times 10^{-9}}\right) 0.7 \times 10^{-13}; \qquad \Delta a_\tau = \left(\frac{\Delta a_\mu}{3 \times 10^{-9}}\right) 0.8 \times 10^{-6}$$

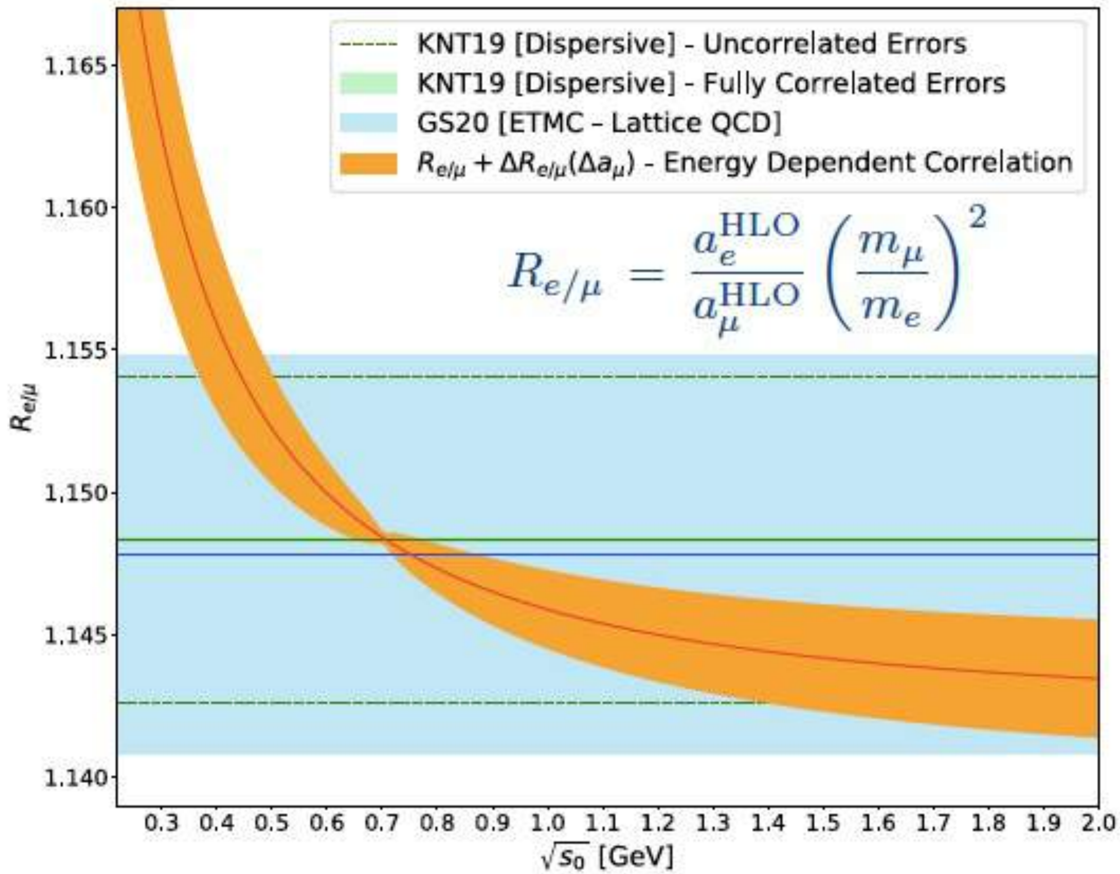
Giudice, Paradisi & MP, JHEP 2012

Shift of electron g-2



Shifts $\Delta\sigma(s)$ to fix Δa_μ only slightly change Δa_e

Keshavarzi, Marciano, MP, Sirlin, PRD 2020



Good agreement between lattice [Giusti & Simula 2020] and KNT19.
Possible future bounds on very low energy shifts $\Delta\sigma(s)$?

Keshavarzi, Marciano, MP, Sirlin, PRD 2020