FITTED

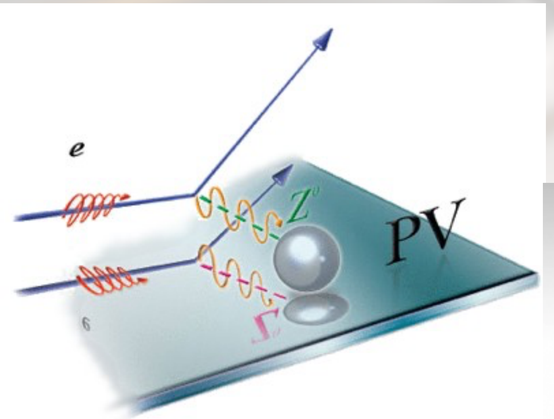
FITs to Electroweak, Hadronic and Nuclear Precision Data

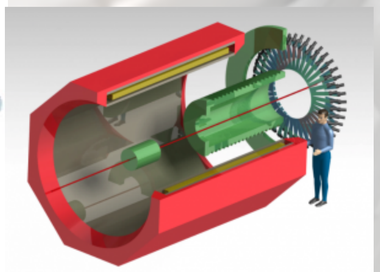
PI: Jens Erler

Presented by Mikhail Gorshteyn

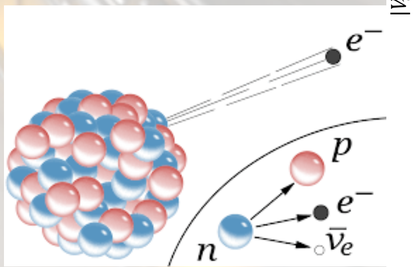
Hadron Physics in Horizon Europe INFRASERV

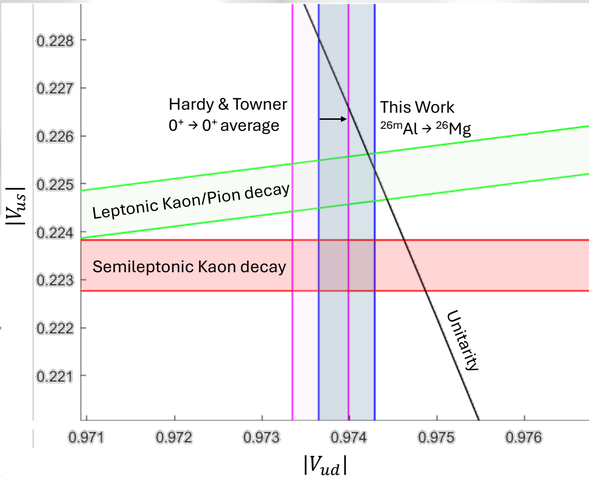
Town Meeting, Nantes, July 2025





JOHANNES GUTENBERG UNIVERSITÄT MAINZ





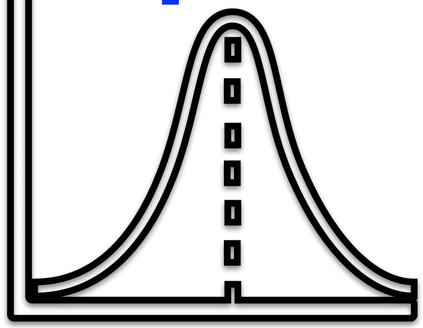
Introduction

* Standard Model (SM) unreasonably successful
* Still no sign of physics beyond the SM (BSM) at the LHC
  - ➡ Look for small deviations
  - ➡ only possible if SM is overconstrained
  - ➡ need maximal number of precision observables for which experimental and theoretical uncertainties can be controlled simultaneously
* very high precision reached
  - ➡ reevaluate all sources of uncertainties and correlations, including theoretical
  - ➡ the higher the precision, the more issues enter interpretation of precision measurements

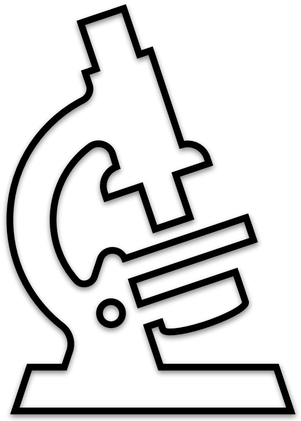
 welcome bonus: brings previously disjoint physics communities together

- ➡ expect novel synergetic effect

Z pole

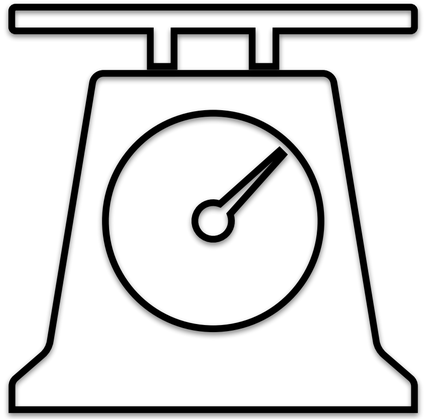


low-energy precision

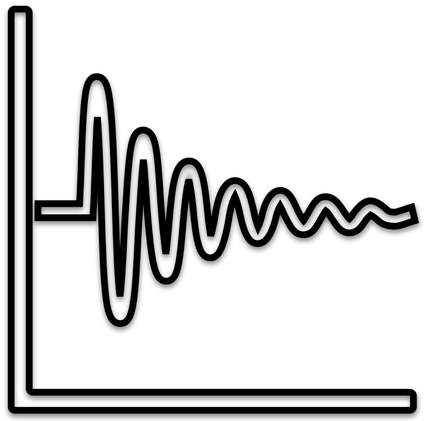


Fits to SM & BSM

M_H, m_t
M_W, Γ_W



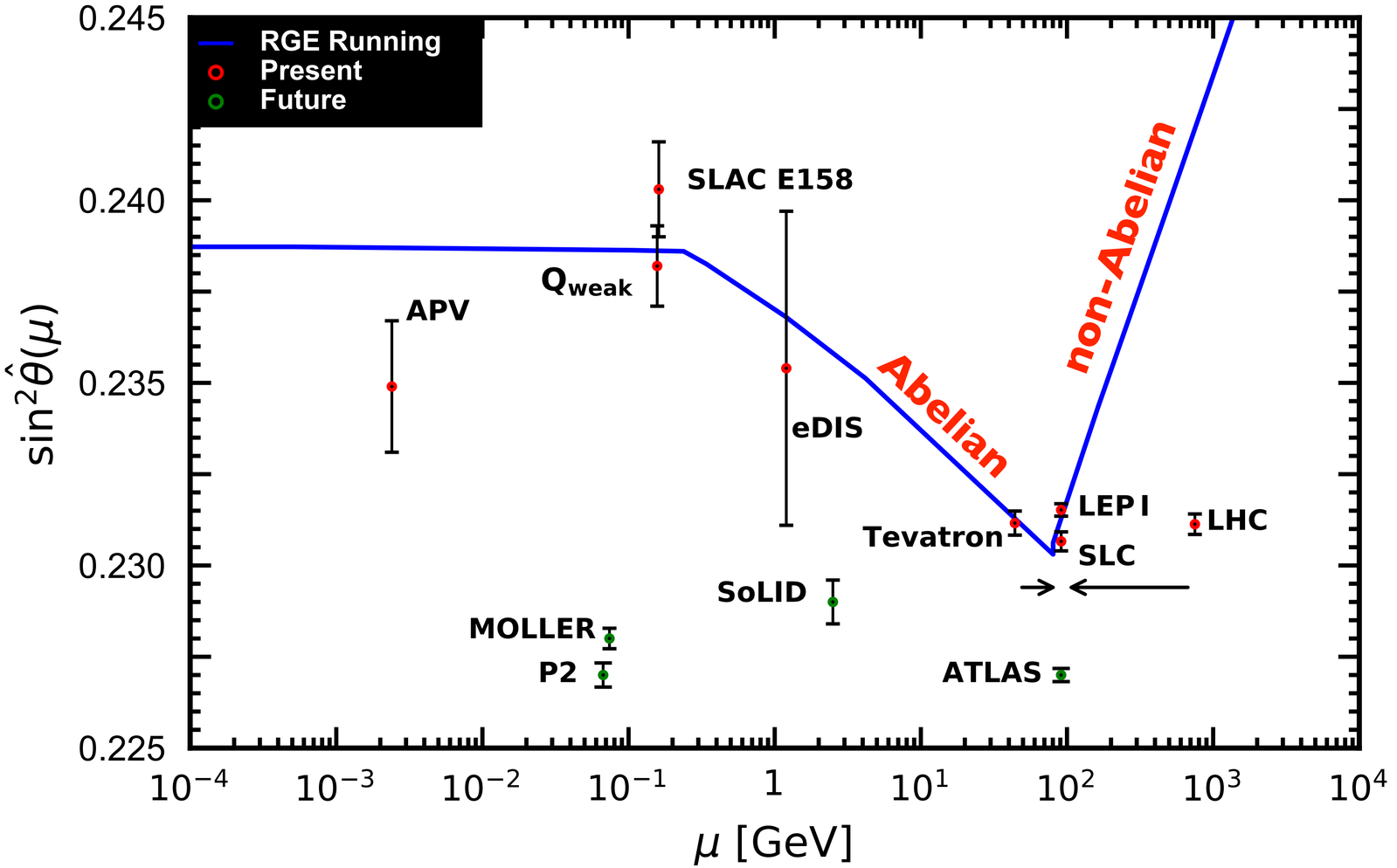
m_c, m_b, $\Delta\alpha$…



This proposal

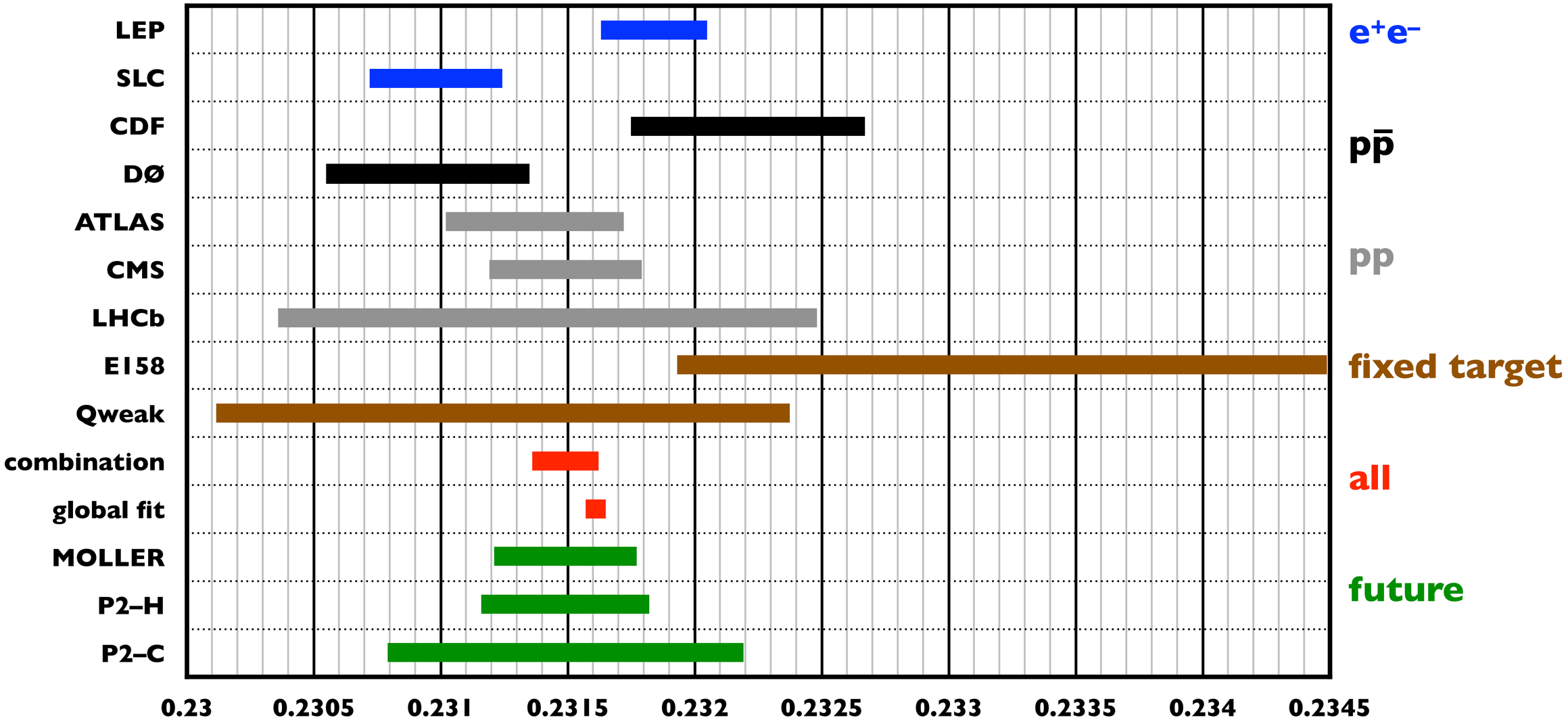
* global fits to electroweak precision data including those with $\sqrt{Q^2} \lesssim \Lambda_{QCD}$
* assess & include theoretical uncertainties
* assess & include theoretical correlations between otherwise independent observables
* most notorious sources of theory uncertainty are of hadronic nature
  - ➡ form factors, parton distribution functions, hadronic and nuclear corrections etc.
  - ➡ PVES — P2, MREX@MESA (Mainz) and MOLLER, SOLID@CEBAF (JLab)
  - ➡ *Weak charges* of proton, electron, ^{12}C, heavier nuclei
  - ➡ Neutron and nuclear beta decays, V_{ud} and CKM unitarity
  - ➡ Precise nuclear radii are necessary, typically from atomic data
  - ➡ γZ-, $\gamma\gamma$- and γW-boxes contribute non-negligibly to error budget

Running $\overline{\text{MS}}$ weak mixing angle

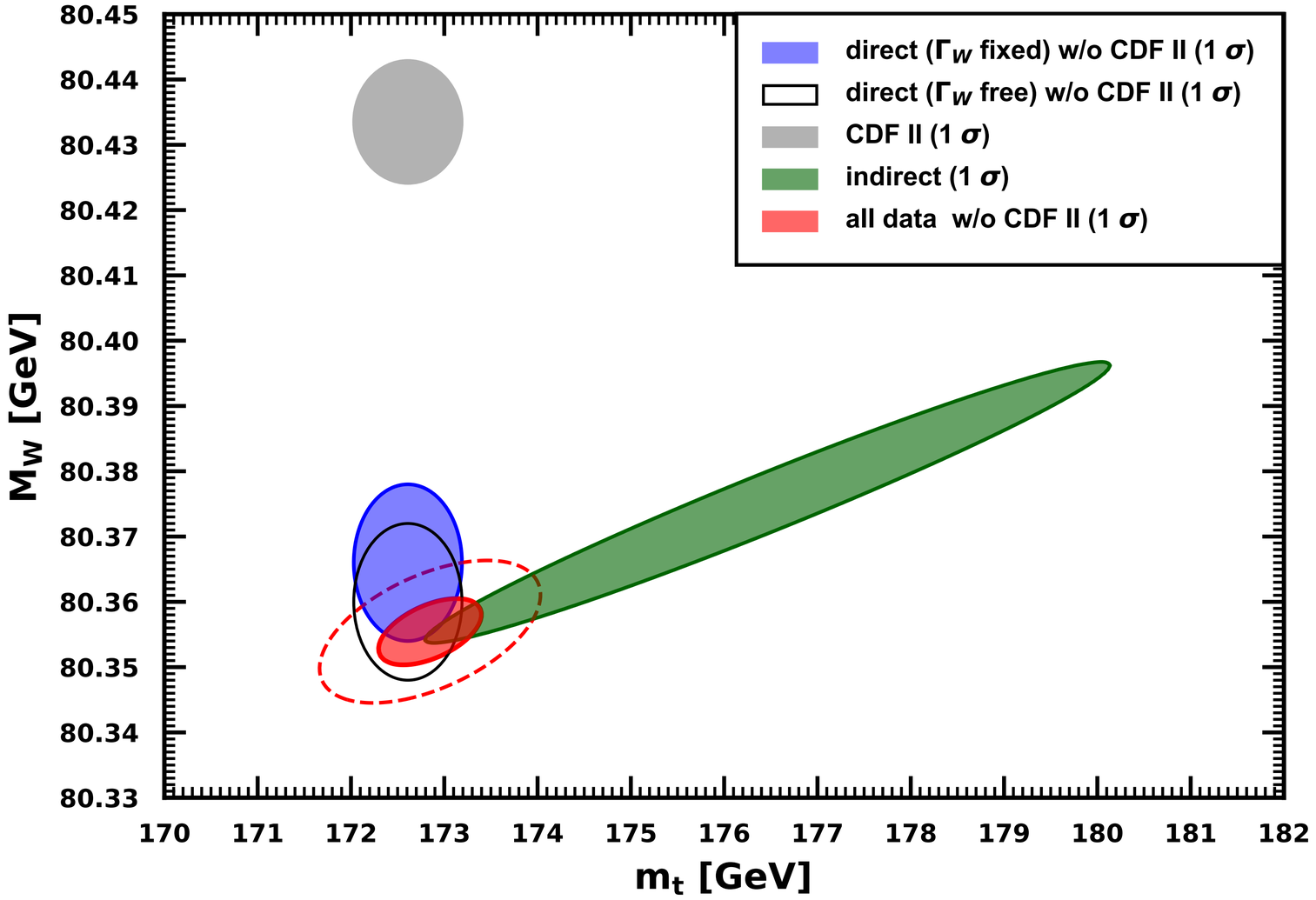


updated from
Ferro-Hernández & JE
***JHEP* 12 (2023) 131**

$\sin^2\theta^{\ell}_{\text{eff}}$ anno 2024



$M_W - m_t$



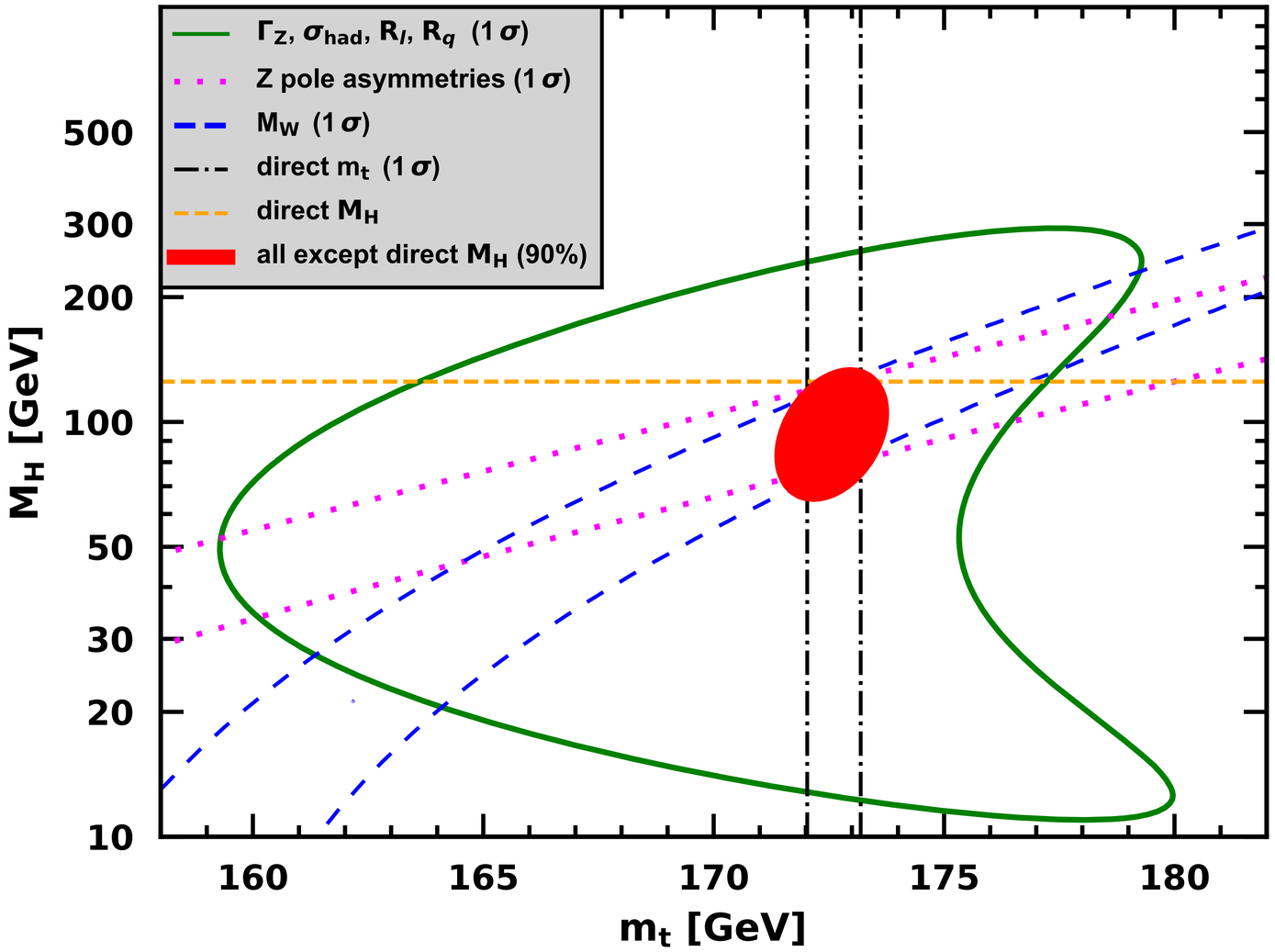
m_t = 175.2 ± 1.8 GeV (indirect)

1.4 σ above

m_t = 172.61 ± 0.58 GeV (Tevatron + LHC)

Freitas & JE, PDG (2024)
figure: Rodolfo Ferro

$M_H - m_t$



χ^2/d.o.f. = 49.5/47

(p-value = 37%)

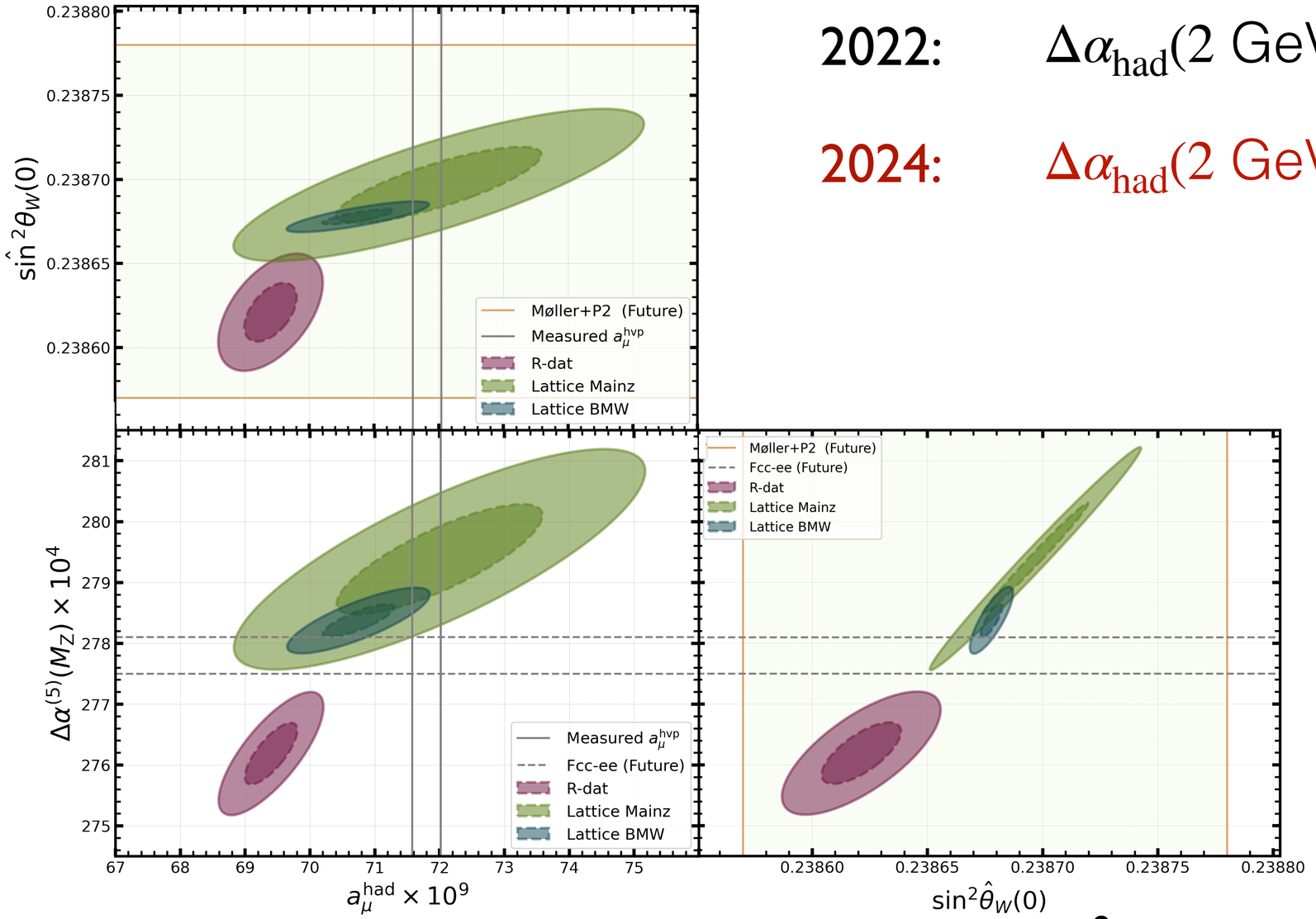
$M_H = 97^{+18}_{-16}$ GeV (indirect)

1.6 σ below

$M_H = 125.10 \pm 0.09$ GeV (LHC)

Freitas & JE, PDG (2024)
figure: Rodolfo Ferro

$g_\mu - 2$, $\alpha(M_Z)$ and $\sin^2\theta_W(0)$



2022: $\Delta\alpha_{had}(2\ \text{GeV}) = (58.84 \pm 0.51) \times 10^{-4}$

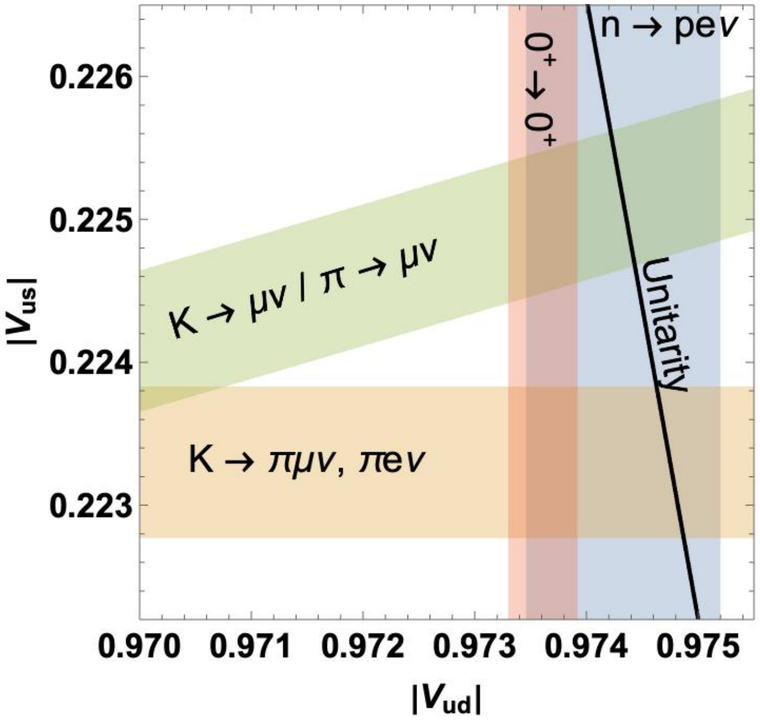
2024: $\Delta\alpha_{had}(2\ \text{GeV}) = (60.30 \pm 0.43) \times 10^{-4}$

$\Delta M_W = -2.7$ MeV

$\Delta M_H = -7.0$ GeV

Ferro-Hernàndez, Kuberski, JE
Phys. Rev. Lett. 133 (2024) 17

Cabibbo unitarity: anomaly detected

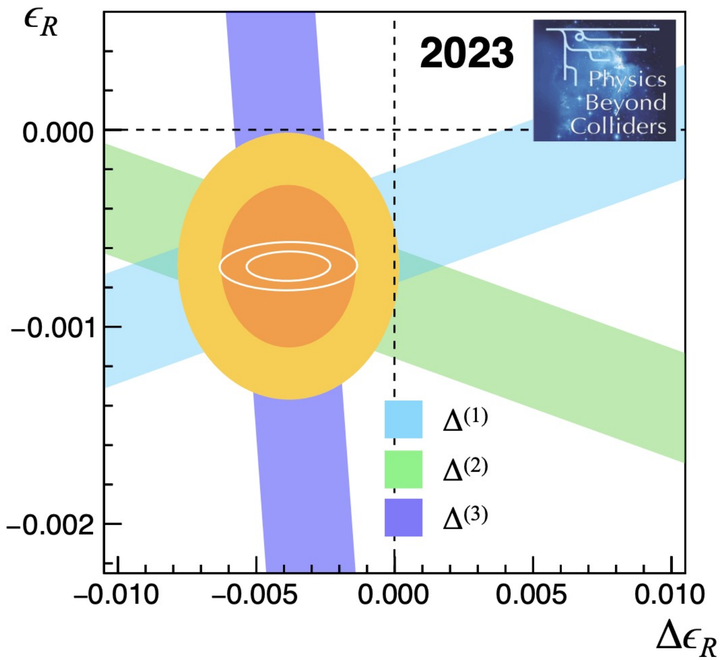


Reevaluation of hadron structure-dependent RC to beta decays —> 2.5-4σ deficit!

Seng, MG, Patel, Ramsey-Musolf arXiv:1807.10197; 1812.03352; 1812.04229

May be explained by BSM:
RH currents that couple differently to light and strange quarks

Cirigliano, Crivellin, Hoferichter, Moulson, arXiv: 2208.11707



Cabibbo unitarity: is there an anomaly?

MG, Ohayon, Sahoo, Seng
arXiv:2502.17070

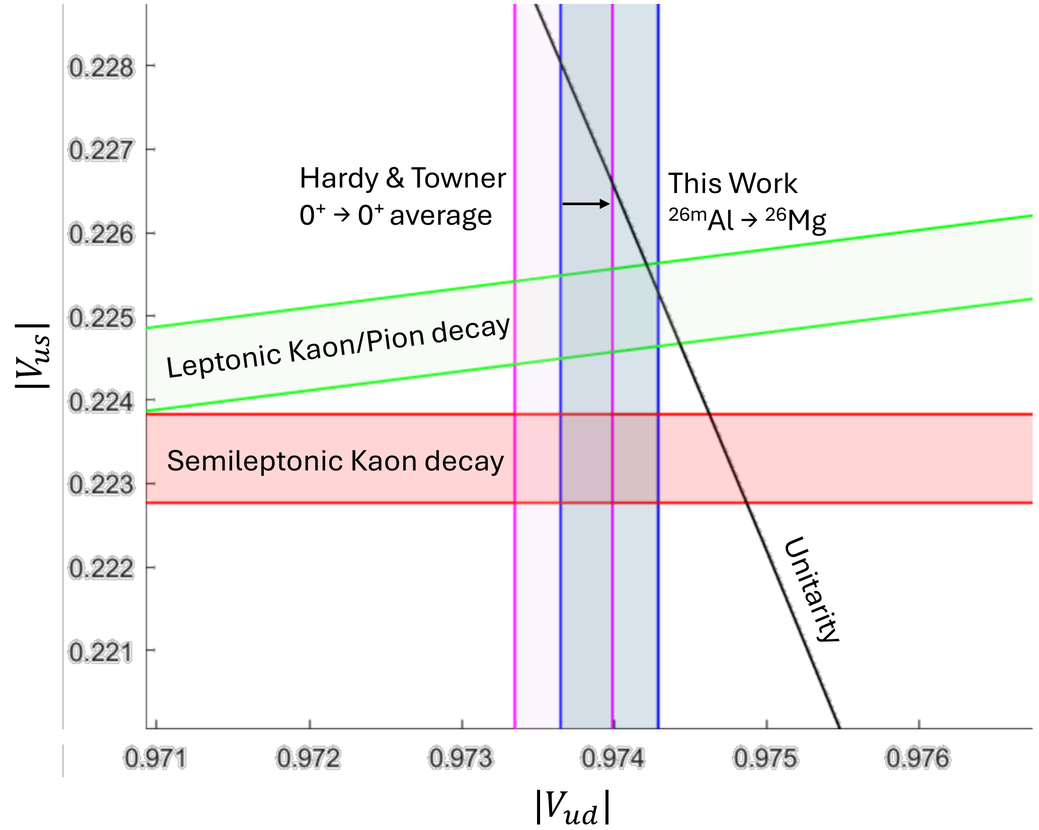
But size of anomaly depends on hadronic and nuclear corrections!

Careful account on nuclear size effects;

Reanalysis of theory ingredients in radii extracted from atomic data (ISOLDE + μ X-rays)

Improved uncertainties and correlations

CKM unitarity deficit halved 2.5σ —> 1.3σ



Goals & Impact

* Discrepancies (tensions) are the result of SM being overconstrained
* Significance of discrepancies based on (hadronic/nuclear) SM corrections
* Alleviating tensions by removing some of the constraints — beyond SM
* global analysis of all relevant electroweak data permits interpretation within systematic framework of the SM effective field theory (SMEFT)
* This project will address all these issues simultaneously

➡ connection with measurements at high-energy frontier, e.g., mass measurements and Drell-Yan processes at the LHC

➡ link high-energy, hadronic, nuclear, and atomic physics communities

➡ establish and exploit connections with mathematical physics (Calabi-Yau manifolds - multi loop Feynman integral analogy)

Participating groups

* JGU Mainz
  (Jens Erler, Mikhail Gorchtein, Hans Jockers, Hubert Spiesberger, Stefan Weinzierl)
  Global fit in SM (JE), Radiative and hadronic corrections to LE obs. (MG,HS), Amplitudes & multiloop RC (SW), Mathematical Physics (HJ)
* ETH Zürich and PSI (Adrian Signer)
  Radiative corrections
* University of Pittsburgh (Ayres Freitas)
  Global fit in SM, two-loop RC
* University of Tennessee at Knoxville (Chien-Yeah Seng)
  Radiative and hadronic corrections to LE observables
* University of Freiburg (Stefan Dittmaier)
  EW corrections at colliders; BSM models
* University of Alberta (Andrzej Czarnecki)
  EW corrections at low energies

Jens Erler and Ayres Freitas have contributed to the EW review in PDG for many years through 2024

Budget

* 245 k€: to train a PhD student over a 4-year period to become an expert in the area of global fits to electroweak, hadronic and nuclear precision data
* 20 k€ (5 k€ per year) for traveling to schools, conferences and workshops
* we plan to organize two workshops related to *FITTED*, where we hope to benefit from support by the ECT* and the MITP (Mainz)