Impact of correlations between a_μ and α_{QED} on the EW fit

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Approaches considered for treating the a_μ - α_{QED} correlations

Studied approaches probing different hypotheses concerning the possible source(s) of the a_μ tension(s) :

(0) Scaling factor applied to the HVP contribution from some energy range of the hadronic spectrum

→ Approaches taking into account (*for the first time*) the full correlations between the uncertainties of the HVP contributions to a_μ and α_{QED} , based on input from DHMZ 19 (arXiv:1908.00921):
correlations between points/bins of a measurement in a given channel, between different measurements in the same channel, between different channels; full treatment of the BABAR-KLOE tension in the $\pi^+\pi^-$ channel

Computation (Energy range)	$a_\mu^{\text{HVP, LO}}$ $[10^{-10}]$	$\Delta\alpha_{\text{had}}(M_Z^2)$ $[10^{-4}]$	ρ
Phenomenology (Full HVP)	694.0 ± 4.0	275.3 ± 1.0	44%
Phenomenology ([Th.; 1.8 GeV])	635.5 ± 3.9	55.4 ± 0.4	86%
Phenomenology ([Th.; 1 GeV])	539.8 ± 3.8	36.3 ± 0.3	99.5%
Lattice (Full HVP)BMW 20 (v1)	712.4 ± 4.5	-	-

(1) Cov. matrix of a_μ and α_{QED} (Pheno) described by a nuisance parameter (NP_1) impacting both quantities (used to shift a_μ to some "target" value - coherent shift applied to α_{QED}) and another one (NP_2) impacting only α_{QED} (used in the EW fit)
Note: "target" values chosen in order to reach agreement with the BMW 20 prediction / Experimental a_μ ($\pm 1\sigma$)

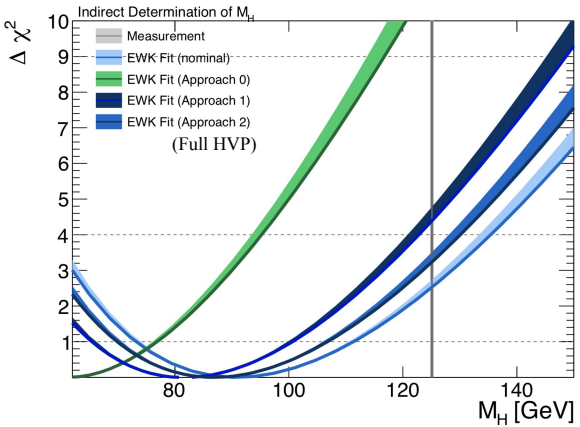
Uncertainty components	$a_\mu^{\text{HVP, LO}}$	$\Delta\alpha_{\text{had}}(M_Z^2)$
NP_1	$\sigma(a_\mu^{\text{HVP, LO}})$	$\sigma(\Delta\alpha_{\text{had}}(M_Z^2)) \cdot \rho$
NP_2	0	$\sigma(\Delta\alpha_{\text{had}}(M_Z^2)) \cdot \sqrt{1-\rho^2}$

(2) Include the HVP contribution to a_μ as extra parameter in the EW fit, constrained by the Pheno & BMW 20 values
Note: Also accounted for the coherent impact of α_S on the HVP contribution and on the EW fit

Results: comparing the Phenomenology & BMW 20 values

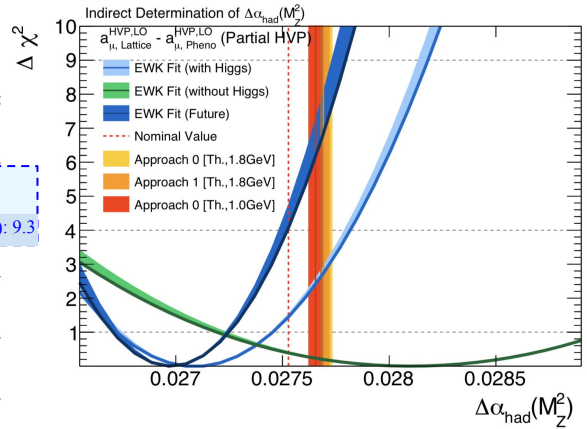
$a_\mu^{\text{HVP, LO}}$ shift (Energy range)	*Approach* 0		*Approach* 1		
	Scaling factor	$\Delta'\alpha_{\text{had}}(M_Z^2)$	Shift NP_1	$\sigma'\left(\Delta\alpha_{\text{had}}(M_Z^2)\right)$	$\Delta'\alpha_{\text{had}}(M_Z^2)$
$a_{\mu\,(\text{Lattice})}^{\text{HVP, LO}} - a_{\mu\,(\text{Pheno})}^{\text{HVP, LO}}$ (Full HVP)	1.027	0.02826	4.6	$9.0 \cdot 10^{-5}$	0.02774
$(a_{\mu\,(\text{Lattice})}^{\text{HVP, LO}} - 1\sigma) - a_{\mu\,(\text{Pheno})}^{\text{HVP, LO}}$ (Full HVP)	1.020	0.02808	3.5	$9.0 \cdot 10^{-5}$	0.02769
$a_{\mu\,(\text{Lattice})}^{\text{HVP, LO}} - a_{\mu\,(\text{Pheno})}^{\text{HVP, LO}}$ ([Th.; 1.8 GeV])	1.029	0.02769	4.7	$9.5 \cdot 10^{-5}$	0.02768
$(a_{\mu\,(\text{Lattice})}^{\text{HVP, LO}} - 1\sigma) - a_{\mu\,(\text{Pheno})}^{\text{HVP, LO}}$ ([Th.; 1.8 GeV])	1.022	0.02765	3.5	$9.5 \cdot 10^{-5}$	0.02764
$a_{\mu\,(\text{Lattice})}^{\text{HVP, LO}} - a_{\mu\,(\text{Pheno})}^{\text{HVP, LO}}$ ([Th.; 1 GeV])	1.034	0.02765	-	-	-
$(a_{\mu\,(\text{Lattice})}^{\text{HVP, LO}} - 1\sigma) - a_{\mu\,(\text{Pheno})}^{\text{HVP, LO}}$ ([Th.; 1 GeV])	1.026	0.02762	-	-	-

→ Large scaling factors (w.r.t. exp. uncertainties) & significant shifts of NP_1



$a_\mu^{\text{HVP, LO}}$ shift (Energy range)	Nominal		*Approach* 0		*Approach* 1		*Approach* 2	
	$\Delta'\alpha_{\text{had}}(M_Z^2)$	χ^2/ndf	$\Delta'\alpha_{\text{had}}(M_Z^2)$	χ^2/ndf	$\Delta'\alpha_{\text{had}}(M_Z^2)$	χ^2/ndf	$\Delta'\alpha_{\text{had}}(M_Z^2)$	χ^2/ndf
	0.02753	18.6/16 (p=0.29)	-	-	-	-	0.02753	28.1/17 (p=0.04)
$a_{\mu\,(\text{Lattice})}^{\text{HVP, LO}} - a_{\mu\,(\text{Pheno})}^{\text{HVP, LO}}$ (Full HVP)	-	-	0.02826	27.6/16 (p=0.04)	0.02774	20.3/16 (p=0.21)	-	
$a_{\mu\,(\text{Lattice})}^{\text{HVP, LO}} - a_{\mu\,(\text{Pheno})}^{\text{HVP, LO}}$ ([Th.; 1.8 GeV])	-	-	0.02769	19.9/16 (p=0.22)	0.02768	19.8/16 (p=0.23)	-	-
$a_{\mu\,(\text{Lattice})}^{\text{HVP, LO}} - a_{\mu\,(\text{Pheno})}^{\text{HVP, LO}}$ ([Th.; 1.0 GeV])	-	-	0.02765	19.6/16 (p=0.24)	-	-	-	-

χ^2(BMW20-Pheno): 9.3



→ Addressing the BMW 20 - Pheno difference for a_μ has little impact on the EW fit, except for the unrealistic scenario rescaling the full HVP contribution

Note: Similar conclusions for the comparison with the Experimental a_μ value (see backup)

Backup

Scaling factors and NP shifts

$a_\mu^{\text{HVP, LO}}$ shift (Energy range)	*Approach* 0		*Approach* 1		
	Scaling factor	$\Delta'\alpha_{\text{had}}(M_Z^2)$	Shift NP_1	$\sigma'\left(\Delta\alpha_{\text{had}}(M_Z^2)\right)$	$\Delta'\alpha_{\text{had}}(M_Z^2)$
$a_{\mu\,(\text{Lattice})}^{\text{HVP, LO}} - a_{\mu\,(\text{Pheno})}^{\text{HVP, LO}}$ (Full HVP)	1.027	0.02826	4.6	$9.0 \cdot 10^{-5}$	0.02774
$(a_{\mu\,(\text{Lattice})}^{\text{HVP, LO}} - 1\sigma) - a_{\mu\,(\text{Pheno})}^{\text{HVP, LO}}$ (Full HVP)	1.020	0.02808	3.5	$9.0 \cdot 10^{-5}$	0.02769
$a_{\mu\,(\text{Lattice})}^{\text{HVP, LO}} - a_{\mu\,(\text{Pheno})}^{\text{HVP, LO}}$ ([Th.; 1.8 GeV])	1.029	0.02769	4.7	$9.5 \cdot 10^{-5}$	0.02768
$(a_{\mu\,(\text{Lattice})}^{\text{HVP, LO}} - 1\sigma) - a_{\mu\,(\text{Pheno})}^{\text{HVP, LO}}$ ([Th.; 1.8 GeV])	1.022	0.02765	3.5	$9.5 \cdot 10^{-5}$	0.02764
$a_{\mu\,(\text{Lattice})}^{\text{HVP, LO}} - a_{\mu\,(\text{Pheno})}^{\text{HVP, LO}}$ ([Th.; 1 GeV])	1.034	0.02765	-	-	-
$(a_{\mu\,(\text{Lattice})}^{\text{HVP, LO}} - 1\sigma) - a_{\mu\,(\text{Pheno})}^{\text{HVP, LO}}$ ([Th.; 1 GeV])	1.026	0.02762	-	-	-
$a_\mu^{\text{Exp}} - a_\mu^{\text{SM (Pheno)}}$ (Full HVP)	1.037	0.02856	6.6	$9.0 \cdot 10^{-5}$	0.02782
$(a_\mu^{\text{Exp}} - 1\sigma) - a_\mu^{\text{SM (Pheno)}}$ (Full HVP)	1.028	0.02831	5.0	$9.0 \cdot 10^{-5}$	0.02775
$a_\mu^{\text{Exp}} - a_\mu^{\text{SM (Pheno)}}$ ([Th.; 1.8 GeV])	1.041	0.02776	6.6	$9.5 \cdot 10^{-5}$	0.02774
$(a_\mu^{\text{Exp}} - 1\sigma) - a_\mu^{\text{SM (Pheno)}}$ ([Th.; 1.8 GeV])	1.031	0.02770	5.0	$9.5 \cdot 10^{-5}$	0.02769
$a_\mu^{\text{Exp}} - a_\mu^{\text{SM (Pheno)}}$ ([Th.; 1 GeV])	1.048	0.02771	-	-	-
$(a_\mu^{\text{Exp}} - 1\sigma) - a_\mu^{\text{SM (Pheno)}}$ ([Th.; 1 GeV])	1.036	0.02766	-	-	-

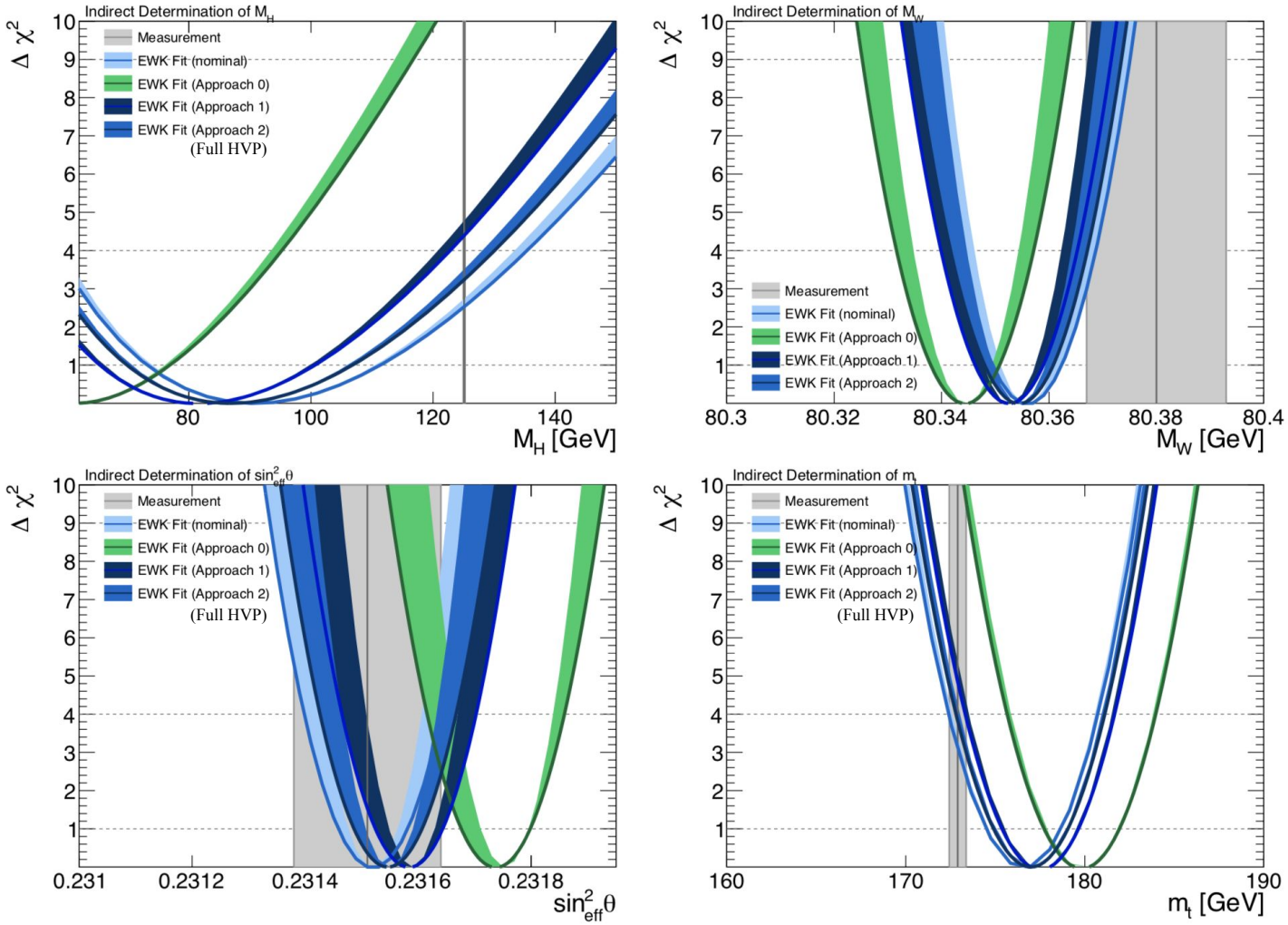
→ Large scaling factors (w.r.t. uncertainties) & significant shifts of NP_1

EW fit inputs and χ^2 results

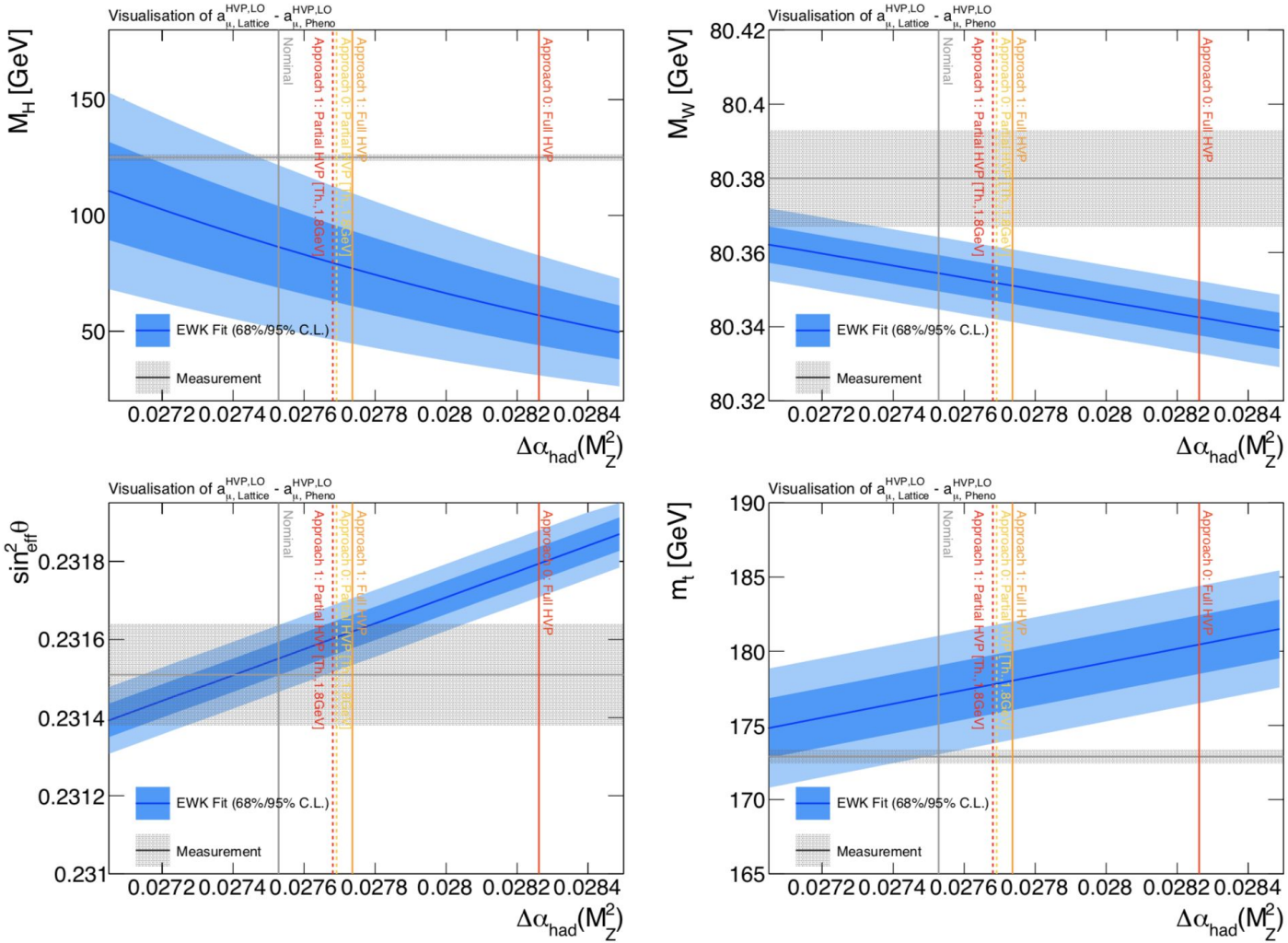
LEP/LHC/Tevatron					
M_Z [GeV]	91.188 ± 0.002	R_c^0	0.1721 ± 0.003	M_H [GeV]	125.09 ± 0.15
$\sigma^0_{\rm had}$ [nb]	41.54 ± 0.037	R_b^0	0.21629 ± 0.00066	M_W [GeV]	80.380 ± 0.013
Γ_Z [GeV]	2.495 ± 0.002	A_c	0.67 ± 0.027	m_t [GeV]	172.9 ± 0.5
A_l (SLD)	0.1513 ± 0.00207	A_l (LEP)	0.1465 ± 0.0033	$\sin^2\theta^l_{\rm eff}$	0.2314 ± 0.00023
$A^l_{\rm FB}$	0.0171 ± 0.001	m_c [GeV]	$1.27^{+0.07}_{-0.11}$ GeV	**After HL-LHC**	
$A^c_{\rm FB}$	0.0707 ± 0.0035	m_b [GeV]	$4.20^{+0.17}_{-0.07}$ GeV	M_W [GeV]	80.380 ± 0.008
$A^b_{\rm FB}$	0.0992 ± 0.0016	$\alpha_s(M_Z)$	0.1198 ± 0.003	$\sin^2\theta^l_{\rm eff}$	0.2314 ± 0.00012
R^0_l	20.767 ± 0.025	$\Delta\alpha^{(5)}_{\rm had}(M_Z^2)$ $[10^{-5}]$	2760 ± 9	m_t [GeV]	172.9 ± 0.3

$a_\mu^{\rm HVP,\,LO}$ shift (Energy range)	Nominal $\Delta'\alpha_{\rm had}(M_Z^2)$	Nominal χ^2/ndf	*Approach* 0 $\Delta'\alpha_{\rm had}(M_Z^2)$	*Approach* 0 χ^2/ndf	*Approach* 1 $\Delta'\alpha_{\rm had}(M_Z^2)$	*Approach* 1 χ^2/ndf	*Approach* 2 $\Delta'\alpha_{\rm had}(M_Z^2)$	*Approach* 2 χ^2/ndf
	0.02753	18.6/16 (p=0.29)	-	-	-	-	0.02753	28.1/17 (p=0.04) χ^2(BMW20-Pheno): 9.3
$a_\mu^{\rm HVP,\,LO}$ (Lattice) $- a_\mu^{\rm HVP,\,LO}$ (Pheno) (Full HVP)	-	-	0.02826	27.6/16 (p=0.04)	0.02774	20.3/16 (p=0.21)	-	
$a_\mu^{\rm HVP,\,LO}$ (Lattice) $- a_\mu^{\rm HVP,\,LO}$ (Pheno) ([Th.; 1.8 GeV])	-	-	0.02769	19.9/16 (p=0.22)	0.02768	19.8/16 (p=0.23)	-	-
$a_\mu^{\rm HVP,\,LO}$ (Lattice) $- a_\mu^{\rm HVP,\,LO}$ (Pheno) ([Th.; 1.0 GeV])	-	-	0.02765	19.6/16 (p=0.24)	-	-	-	-
$a_\mu^{\rm Exp} - a_\mu^{\rm SM}$ (Pheno) (Full HVP)	-	-	0.02856	33.6/16 (p=0.01)	0.02782	21.2/16 (p=0.17)	-	-
$a_\mu^{\rm Exp} - a_\mu^{\rm SM}$ (Pheno) ([Th.; 1.8 GeV])	-	-	0.02776	20.6/16 (p=0.19)	0.02774	20.4/16 (p=0.20)	-	-
$a_\mu^{\rm Exp} - a_\mu^{\rm SM}$ (Pheno) ([Th.; 1.0 GeV])	-	-	0.02771	20.1/16 (p=0.22)	-	-	-	-

EW fit results: χ^2 scans



EW fit results: parameter scans for varying $\Delta\alpha_{had}(M_Z^2)$



EW fit results: indirect determination of $\Delta\alpha_{had}(M_Z^2)$