New Calculations of the Masses of the W, Z and Higgs Bosons

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Abstract

In our previous papers, we constructed a model for the masses of elementary particles and calculated the masses of elementary particles especially in atomic units. In this paper, based on the recent more accurate measurements of the masses of the W boson, the Z boson and the Higgs bosons, we revise our previous calculations and give news values of their masses which are 157248.297520661, 178449.921111111 and 244920.803503690 in atomic units, or 80353.714694 (24) MeV, 91187.722057(27) MeV and 125154.273069(26) MeV respectively. Compared to the latest and most accurate measured values of the masses of the W boson, the Z boson and the Higgs bosons which are 80360.2(9.9) MeV, 91187.6(2.1) MeV and 125.11(11) GeV respectively, our new calculated values are very precise if they are correct.

Keywords: mass, the W boson, the Z boson, the Higgs boson, atomic units.

1. Hartree-Chen atomic units

In our previous papers [1], we redefined Hartree atomic units to Hartree-Chen atomic units as follows.

Hartree atomic units (au):

$$\hbar_{au} = e_{au} = a_{0/au} = m_{e/au} = 1,\ \ \hbar_{au} = \frac{h_{au}}{2\pi} = 1,\ \ h_{au} = 2\pi$$

Hartree-Chen atomic units (still abbreviated as au):

$$\hbar_{au} = e_{au} = a_{0/au} = 1,\ \ m_{e/au} = 1 + \frac{1}{c_{au}^{\ 4}},\ \ m_{e^+/au} = 1 - \frac{1}{c_{au}^{\ 4}}$$

$$\hbar_{au} = \frac{h_{au}}{(2\pi)_{au}} = 1,\ \ h_{au} = (2\pi)_{au} = \frac{4\times157}{100} = 6.28$$

$$(\sqrt{2})_{au} = \frac{141}{100},\ \ (\sqrt{3})_{au} = \frac{173}{100},\ \ (\pi)_{au} = \frac{2\times157}{100} = \frac{314}{100}$$

$$(\sqrt{2})_{au} + (\sqrt{3})_{au} = (\pi)_{au},\ \ (\frac{\sqrt{2}}{2})_{au} + (\frac{\sqrt{3}}{2})_{au} = (\frac{\pi}{2})_{au}$$

$$c_{au}=\frac{c}{v_e}=\sqrt{112\times(168-\frac{1}{3}+\frac{1}{12\cdot 47}-\frac{1}{14\cdot 112\cdot(2\cdot 173+1)+7/24})}$$
$$=137.035999074627$$

h_{au} : the Planck constant in Hartree-Chen atomic units

c_{au} : the speed of light in vacuum in Hartree-Chen atomic units

c : the speed of light in vacuum

v_e : the line speed of the ground state electron of H atom in Bohr model

In this paper, we still use atomic units (au) referring to Hartree-Chen atomic units.

2. Formulas of the Fine-structure Constant and the Speed of Light in Atomic Units

In our previous papers [2-7], we constructed formulas of the fine-structure constant and the speed of light in atomic units with 2π-e formula and other principles as follows.

$2\pi-e$ formula:

$$2\pi=(\frac{e}{e^{\gamma_c}})^2=e^2\frac{e^2}{(\frac{2}{1})^3}\frac{e^2}{(\frac{3}{2})^5}\frac{e^2}{(\frac{4}{3})^7}\cdots$$

$$(2\pi)_{Chen-k}=(\frac{e}{e^{\gamma_{c,k}}})^2=e^2\frac{e^2}{(\frac{2}{1})^3}\frac{e^2}{(\frac{3}{2})^5}\cdots\frac{e^2}{(\frac{k+1}{k})^{2k+1}}$$

$$\alpha_1=\frac{36}{7(2\pi)_{Chen-112}}\frac{1}{112+\frac{1}{75^2}}=1/137.035999037435$$

$$\alpha_2=\frac{13(2\pi)_{Chen-278}}{100}\frac{1}{112-\frac{1}{64\cdot 3\cdot 29}}=1/137.035999111818$$

$$c_{au}=\frac{c}{v_e}=\frac{1}{\alpha_c}=\frac{1}{\sqrt{\alpha_1\alpha_2}}$$
$$=\sqrt{112(168-\frac{1}{3}+\frac{1}{4\cdot 141}-\frac{1}{14\cdot 112(2\cdot 173+1)+\frac{7}{24}})}$$
$$=\sqrt{112(167+\frac{126}{188}-\frac{1}{4\cdot 141}-\frac{1}{14\cdot 112(2\cdot 173+1)+\frac{7}{24}})}$$
$$=\sqrt{112(166+\frac{2\cdot 157}{188}-\frac{1}{4\cdot 141}-\frac{1}{14\cdot 112(2\cdot 173+1)+\frac{7}{24}})}$$
$$=137.035999074627$$

$$\frac{c_{au}}{2}=\sqrt{56(84-\frac{1}{6}+\frac{1}{8\cdot 141}-\frac{1}{56^2(2\cdot 173+1)+\frac{7}{12}})}$$

$$=\sqrt{56(83+\frac{157}{188}-\frac{1}{8\cdot 141}-\frac{1}{56^2(2\cdot 173+1)+\frac{7}{12}})}$$

$$=137.035999074627/2$$

Relationships with nuclides:

$$^{56}_{26}Fe_{30}\quad ^{63,65}_{29}Cu_{34,36}\quad ^{82,83,84}_{36}Kr_{46,47,48}\quad ^{100}_{44}Ru_{56}\quad ^{112}_{48}Cd_{64}\quad ^{107,109}_{47}Ag_{60,62}\quad ^{140,142}_{58}Ce_{82,84}$$

$$^{136,137,138}_{56}Ba_{80,81,82}\quad ^{157}_{64}Gd_{93}\quad ^{166,167,168}_{68}Er_{98,99,100}\quad ^{169}_{69}Tm_{100}\quad ^{173}_{70}Yb_{103}\quad ^{185,187}_{75}\mathrm{Re}_{110,112}$$

$$^{188}_{76}Os_{112}\quad ^{208}_{82}Pt_{126}\quad ^{209}_{83}Bi^{*}_{126}\quad ^{209}_{84}Po^{*}_{125}\quad ^{210}_{85}At^{*}_{125}\quad ^{223,224}_{87}Fr^{*}_{136,137}\quad ^{232}_{90}Th^{*}_{142}\quad ^{231}_{91}Pa^{*}_{140}$$

$$^{257}_{100}Fm^{*}_{157}\quad ^{264,265}_{103}Lr^{*}_{161,162}\quad ^{273,274}_{107}Bh^{*}_{166,167}\quad ^{276}_{108}Hs^{ie}_{168}\quad ^{278}_{109}Mt^{*}_{169}\quad ^{285}_{112}Cn^{*}_{173}\quad ^{2\cdot 157}_{126}Ch^{ie}_{188}$$

$$^{344,2\cdot 173,348}_{136,137,138}Fy^{ie}_{208,209,210}\quad ^{357}_{141}Ch^{ie}_{216}\quad ^{400}_{157}Ch^{ie}_{243}\quad ^{426}_{169}Ch^{ie}_{257}\quad ^{420}_{168}Ch^{ie}_{262}\quad ^{438}_{173}Ch^{ie}_{265}$$

3. General Formulas of the Masses of Elementary Particles

In atomic units, for an elementary particle, Einstein mass-energy equation should have a more fundamental form as follows [8-9].

Einstein mass-energy equation: $E=mc^2$

In Hartree-Chen atomic units, for an elementary particle:

$$E_{au}=m_{P/au}c_{au}{}^2$$

$$m_{P/au}=\frac{m_P}{m_e/(1+1/c_{au}{}^4)}$$

$$c_{au}{}^2=112(168-\frac{1}{3}+\frac{1}{12\cdot 47}-\frac{1}{14\cdot 112(2\cdot 173+1)+7/12})$$

$$=137.035999074627^2$$

$c_{au}=\dfrac{1}{\sqrt{\alpha_1\alpha_2}}$ is consistent with Maxwell formula $c=\dfrac{1}{\sqrt{\mu_0\varepsilon_0}}$

μ_0: magnetic permeability of vacuum; ε_0: electric permittivity of vacuum

So in the formula of c_{au}, we suppose:

112 is magnetic field factor (MFF),

$168-\dfrac{1}{3}+\dfrac{1}{12\cdot 47}-\dfrac{1}{14\cdot 112(2\cdot 173+1)}$ is electric field factor (EFF)

In our previous papers [8, 9], considering $m_{P/au}$ might have the similar format as c_{au}, we hypothesized the general formula for the masses of elementary particles in atomic units ($m_{P/au}$) as follows.

$$m_{P/au} = \frac{m_P}{m_e/(1+1/c_{au}{}^4)} = [TF(SF \pm \sum 1/SSF)]^{2,\ -2}$$

TF: Time Factor

SF: Space Factor; *SSF*: Sub-space Factor

4. Formulas and Calculations of the W Boson Mass

According to the above general formula for the masses of elementary particles in atomic units and referring to the latest measurements of the W boson mass [10,], we revised our previous formulas to calculate the W boson mass as follows [11].

Electron mass： $m_e = 0.51099895000(15)$ MeV

the measured mass of the W boson (CERN 2024/9/17) [10]:

$m_W = 80360.2(9.9)$ MeV

$$\beta_{W/e} = \frac{m_W}{m_e} = \frac{80360.2(9.9)}{0.51099895000} = 157261(19)$$

Standard Model calculation: $m_W = 80357(6)$ MeV

$$\beta_{W/e} = \frac{m_W}{m_e} = \frac{80357(6)}{0.51099895000} = 157255(12)$$

We guess:

$$\beta_{W/e} \approx 157257 = 9 \cdot 101 \cdot 173 \approx [20(20 - \frac{1}{5} + \frac{1}{36 - \frac{1}{18}})]^2$$

$$\beta_{W/e} \approx 157276 = 4 \cdot 7 \cdot 41 \cdot 137 \approx [20(20 - \frac{1}{5} + \frac{1}{34 + \frac{23}{50}})]^2$$

$$\beta_{W/e} \approx 157248 = 64 \cdot 27 \cdot 7 \cdot 13 \approx [20(20 - \frac{1}{5} + \frac{1}{36 + \frac{9}{13}})]^2$$

We suppose: $\beta_{W/e} \approx 157248 = 64 \cdot 27 \cdot 7 \cdot 13$

The W boson mass in Hartree-Chen atomic units (au):

$$m_{W/au} = \frac{m_W}{m_e/(1+1/c_{au}{}^4)} \approx 157248 = 64 \cdot 27 \cdot 7 \cdot 13$$

$$m_{W/au} = [20(20 - \frac{1}{6} - \frac{1}{165})]^2 = [20(20 - \frac{2}{11} + \frac{1}{110})]^2 = 157248.297520661$$

$$m_{W/au} = [20(20 - \frac{1}{5} + \frac{1}{36 + \frac{2}{3}})]^2 = [20(20 - \frac{2}{11} + \frac{1}{110})]^2 = 157248.297520661$$

$$m_{W/au} = 64 \cdot 27 \cdot 7 \cdot 13 + \frac{1}{3} - \frac{1}{28 - \frac{1}{13}} = 64 \cdot 27 \cdot 7 \cdot 13 + (\frac{6}{11})^2 = 157248.297520661$$

$$m_{W/au} = 64 \cdot 27 \cdot 7 \cdot 13 + \frac{1}{4} + \frac{1}{21 + \frac{1}{23}} = 64 \cdot 27 \cdot 7 \cdot 13 + (\frac{6}{11})^2 = 157248.297520661$$

$$m_W = m_{W/au} \times \frac{m_e}{1 + 1/c_{au}{}^4} = 157248.297520661 \times \frac{0.51099895000(15)}{1 + 1/137.035999074627^4}$$

$= 80353.714694(24)$ MeV

Relationships with nuclides:

$^{20,21,22}_{10}Ne_{10,11,12}$ $^{23}_{11}Na_{12}$ $^{27}_{13}Al_{14}$ $^{28,30}_{14}Si_{14,16}$ $^{40,42}_{20}Ca_{20,22}$ $^{45}_{21}Sc_{24}$ $^{46,48,49,50}_{22}Ti_{24,26,27,28}$

$^{50,51}_{23}V_{27,28}$ $^{54,56,58}_{26}Fe_{28,30,32}$ $^{59}_{27}Co_{32}$ $^{60,61,64}_{28}Ni_{32,33,36}$ $^{72,74}_{32}Ge_{40,42}$ $^{75}_{33}As_{42}$ $^{84}_{36}Kr_{48}$

$^{94,96,98}_{42}Mo_{52,54,56}$ $^{112}_{48}Cd_{64}$ $^{126}_{52}Te_{74}$ $^{132}_{54}Xe_{78}$ $^{137}_{56}Ba_{81}$ $^{157,160}_{64}Gd_{93,96}$ $^{162}_{66}Dy_{96}$

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5. Formulas and Calculations of the Z Boson Mass

We slightly revise our previous calculations of the Z boson mass as follows [11].

Electron mass：$m_e = 0.51099895000(15)$ MeV

the measured mass of the Z boson：$m_Z = 91187.6(2.1)$ MeV [12]

$$\beta_{Z/e} = \frac{m_Z}{m_e} = \frac{91187.6(2.1) \times 10^3}{0.51099895000(15)} = 178450(4)$$

We suppose: $\beta_{Z/e} \approx 178450 = 2 \cdot 25 \cdot 43 \cdot 83$

The Z boson mass in Hartree-Chen atomic units:

$$m_{Z/au} = \frac{m_Z}{m_e / (1 + 1/c_{au}{}^4)} \approx 178450 = 2 \cdot 25 \cdot 43 \cdot 83$$

$$m_{Z/au} = [20(22 - 1 + \frac{1}{8} - \frac{1}{4 \cdot 3 \cdot 25})]^2 = [20(22 - \frac{7}{8} - \frac{1}{4 \cdot 3 \cdot 25})]^2$$

$= 178449.921111111$

$$m_{Z/au} = [20(22 - 1 + \frac{1}{9} + \frac{1}{5 \cdot 19 - \frac{5}{19}})]^2 = [20(22 - \frac{22}{25} + \frac{1}{8 \cdot 3 \cdot 25})]^2$$

$= 178449.921111111$

$$m_{Z/au} = 2 \cdot 25 \cdot 43 \cdot 83 - \frac{1}{12 + \frac{48}{71}} = 2 \cdot 25 \cdot 43 \cdot 83 - \frac{1}{12} + \frac{1}{9 \cdot 25}$$

$$= 2 \cdot 25 \cdot 43 \cdot 83 - \frac{71}{4 \cdot 9 \cdot 25} = 2 \cdot 25 \cdot 43 \cdot 83 - \frac{2}{25} + \frac{1}{4 \cdot 9 \cdot 25}$$

$= 178449.921111111$

$$m_Z = m_{Z/au} \times \frac{m_e}{1 + 1/c_{au}{}^4} = 178449.921111111 \times \frac{0.51099895000(15)}{1 + 1/137.035999074627^4}$$

$= 91187.722057(27)$ MeV

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Relationships with the nuclides:

$^{19}_{9}F_{10}$ $^{35,37}_{17}Cl_{18,20}$ $^{36,38,40}_{18}Ar_{18,20,22}$ $^{39}_{19}K_{20}$ $^{40,42,43}_{20}Ca_{20,22,23}$ $^{46,47,48,50}_{22}Ti_{24,25,26,28}$

$^{55}_{25}Mn_{30}$ $^{56}_{26}Fe_{30}$ $^{66}_{30}Zn_{36}$ $^{83,86}_{36}Kr_{47,50}$ $^{98,99}_{43}Tc^{*}_{55,56}$ $^{100}_{44}Ru_{56}$ $^{118,119,120,122}_{50}Sn_{68,69,70,72}$

$^{140,142}_{58}Ce_{82,84}$ $^{143,146}_{60}Nd_{83,86}$ $^{166,168}_{68}Er_{98,100}$ $^{169}_{69}Tm_{100}$ $^{175,176}_{71}Lu_{104,105}$ $^{185,187}_{75}\mathrm{Re}_{110,112}$

$^{200}_{80}Hg_{120}$ $^{209}_{83}Bi^{*}_{126}$ $^{222}_{86}Rn^{*}_{136}$ $^{257}_{100}Fm^{*}_{157}$ $^{273}_{107}Bh^{*}_{166}$ $^{300}_{120}Ch^{ie}_{180}$ $^{314}_{126}Ch^{ie}_{188}$ $^{346}_{137}Fy^{ie}_{209}$

6. Square Root of the Ratio of the Z Boson Mass to the W Boson Mass

Square root of the ratio of the Z boson mass to the W boson mass is an important parameter in the standard model of particle physics (Standard Model). We try to give formulas and calculations of it.

$$\sqrt{\frac{m_{Z/au}}{m_{W/au}}}=\sqrt{\frac{178449.921111111}{157248.297520661}}=1.06528350909369$$

$$=1+\frac{1}{16}+\frac{1}{8\cdot 9\cdot 5}+\frac{1}{16\cdot 3\cdot 5(2\cdot 3\cdot 11^2+1)}$$

$$=1+\frac{1}{16}+\frac{1}{8\cdot 9\cdot 5}+\frac{1}{16\cdot 3\cdot 5(8\cdot 7\cdot 13-1)}$$

$$=1+\frac{1}{16}+\frac{31\cdot 47}{16\cdot 9\cdot 5(2\cdot 3\cdot 11^2+1)}$$

$$=1+\frac{1}{16}+\frac{7\cdot 13}{9\cdot 5(8\cdot 7\cdot 13-1)}+\frac{1}{16\cdot 9\cdot 5(8\cdot 7\cdot 13-1)}$$

$$=1+\frac{1}{16}+\frac{81}{8\cdot 5(2\cdot 3\cdot 11^2+1)}-\frac{1}{16\cdot 9\cdot 5(2\cdot 3\cdot 11^2+1)}$$

$$=1+\frac{1}{15}-\frac{1}{3(2\cdot 11^2-1)}-\frac{1}{4\cdot 9\cdot 5\cdot (2\cdot 11^2-1)(2\cdot 3\cdot 11^2+1)}$$

$$=1+\frac{1}{15}-\frac{181}{4\cdot 9\cdot 5(2\cdot 3\cdot 11^2+1)}$$

$$=1+\frac{1}{15}-\frac{1}{2\cdot 3\cdot 11^2+1}-\frac{1}{4\cdot 9\cdot 5(2\cdot 3\cdot 11^2+1)}$$

$$=1+\frac{1}{15}-\frac{7\cdot 13}{2\cdot 9\cdot 5(8\cdot 7\cdot 13-1)}+\frac{1}{4\cdot 9\cdot 5(8\cdot 7\cdot 13-1)}$$

Relationships with nuclides:

$^{28,29,30}_{14}Si_{14,15,16}$ $^{31}_{15}P_{16}$ $^{36,38,40}_{18}Ar_{18,20,22}$ $^{40}_{20}Ca_{20}$ $^{46,48}_{22}Ti_{24,26}$ $^{52}_{24}Cr_{28}$

$^{56,57}_{26}Fe_{30,31}$ $^{66}_{30}Zn_{36}$ $^{69,71}_{31}Ga_{38,40}$ $^{83,84}_{36}Kr_{47,48}$ $^{90,91,92,96}_{40}Zr_{50,51,52,56}$

$^{107,109}_{47}Ag_{60,62}$ $^{112}_{48}Cd_{64}$ $^{120,122}_{50}Sn_{70,72}$ $^{136,137}_{56}Ba_{80,81}$ $^{154,155,156}_{64}Gd_{90,91,92}$

$^{180,181}_{73}Ta_{107,108}$ $^{200,201}_{80}Hg_{120,121}$ $^{232}_{90}Th^{*}_{142}$ $^{231}_{91}Pa^{*}_{140}$ $^{300}_{120}Ch^{ie}_{180}$ $^{302}_{121}Ch^{ie}_{181}$

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7. Formulas and Calculations of the Higgs Boson Mass

We slightly revise our previous formulas of the Higgs boson mass as follows [13].

Electron mass： $m_e = 0.51099895000(15)$ MeV

the measured mass of the Higgs boson (2023/7/21) [14]：

$m_H = 125.11(11)$ GeV

$$\beta_{H/e} = \frac{m_H}{m_e} = \frac{125.11(11)\times 10^3}{0.51099895000(15)} = 244834(215)$$

We suppose: $\beta_{H/e} \approx 244920 = 8\times 3\times 5\times 13\times 157$

The Higgs boson mass in Hartree-Chen atomic units:

$$m_{H/au} = \frac{m_H}{m_e/(1+1/c_{au}{}^4)} \approx 244920 = 8\times 3\times 5\times 13\times 157$$

$$m_{H/au} = [22(22+\frac{1}{3}+\frac{1}{7}+\frac{1}{52+\frac{9}{16}})]^2 = [22(22+\frac{1}{2}-\frac{1}{209+\frac{1}{169}})]^2$$

$$= 244920.803503690$$

$$m_{H/au} = [22(22+\frac{1}{3}+\frac{1}{7}+\frac{4^2}{29^2})]^2 = [22(22+\frac{1}{2}-\frac{13^2}{2\cdot 3\cdot 7\cdot 29^2})]^2$$

$$= [22(22+\frac{2(2\cdot 3^6-1)}{3\cdot 7\cdot 29^2})]^2 = [22(22+\frac{7^2\cdot 17}{2\cdot 29^2}-\frac{1}{2\cdot 3\cdot 7\cdot 29^2})]^2$$

$$= 244920.803503690$$

Relationships with nuclides:

${}^{40}_{18}Ar_{22}$ ${}^{50}_{22}Ti_{28}$ ${}^{52}_{24}Cr_{28}$ ${}^{56}_{26}Fe_{30}$ ${}^{63,65}_{29}Cu_{34,36}$ ${}^{89}_{39}Y_{50}$ ${}^{92}_{40}Zr_{52}$ ${}^{100}_{44}Ru_{56}$ ${}^{119}_{50}Sn_{69}$ ${}^{126}_{52}Te_{74}$

${}^{157}_{64}Gd_{93}$ ${}^{169}_{69}Tm_{100}$ ${}^{209}_{83}Bi^{*}_{126}$ ${}^{257}_{100}Tm^{*}_{157}$ ${}^{2\cdot 157}_{126}Ch^{ie}_{188}$ ${}^{2\cdot 173}_{137}Fy^{ie}_{209}$ ${}^{400}_{157}Ch^{ie}_{243}$ ${}^{426}_{169}Ch^{ie}_{257}$

$$m_{H/au} = 8\times 3\times 5\times 13\times 157+\frac{1}{2}+\frac{1}{4}+\frac{1}{19}+\frac{1}{6\cdot 191+\frac{9}{14}}$$

$$= 8\times 3\times 5\times 13\times 157+\frac{8\cdot 5\cdot 13\cdot 157}{19\cdot 5351}+\frac{2\cdot 7\cdot 11}{3\cdot 19\cdot 5351}+\frac{1}{4\cdot 3\cdot 19\cdot 5351}$$

$= 244920.803503690$ (${}^{191}_{77}Ir_{114}$)

If a Higgs boson become a photon, its frequency would be:

$$\nu_H = \frac{244920.80350369\times c_{au}{}^2}{6.28} = 732378139.341935$$

$$= 17\cdot 61\cdot 67\cdot 83\cdot 127+\frac{1}{3}+\frac{1}{116+\frac{1}{4}} = 17\cdot 61\cdot 67\cdot 83\cdot 127+\frac{53}{5\cdot 31} \quad ({}^{127}_{53}I_{74})$$

$$m_H = m_{H/au}\times\frac{m_e}{1+1/c_{au}{}^4} = 244920.80350369\times\frac{0.51099895000(15)}{1+1/137.035999074627^4}$$

$$= 125154.273069(36)\ \text{MeV}$$

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8. Discussion and Conclusion

On 8 April 2022, CDF collaboration reported the measurement of the W boson mass with value of 80433(9.4) MeV which exceeded the prediction of Standard Model (80357(6) MeV) with 7 sigma and implied new physics beyond Standard Model [15]. On 17 September 2024, CMS experiment at LHC of CERN gave new measured value of 80360.2(9.9) MeV which was in line with the predictions of Standard Model. This situation is called the W boson puzzle (**Fig. 1**). The CMS experiment was more consistent with the previous experiments except CDF experiment, so it gave CMS researchers more confidence about their result. Our work is trying to hypothesize formulas to calculate the W boson mass in accordance with the CMS experiment and the predictions of Standard Model, and our calculated value is 80353.714694 (24) MeV.

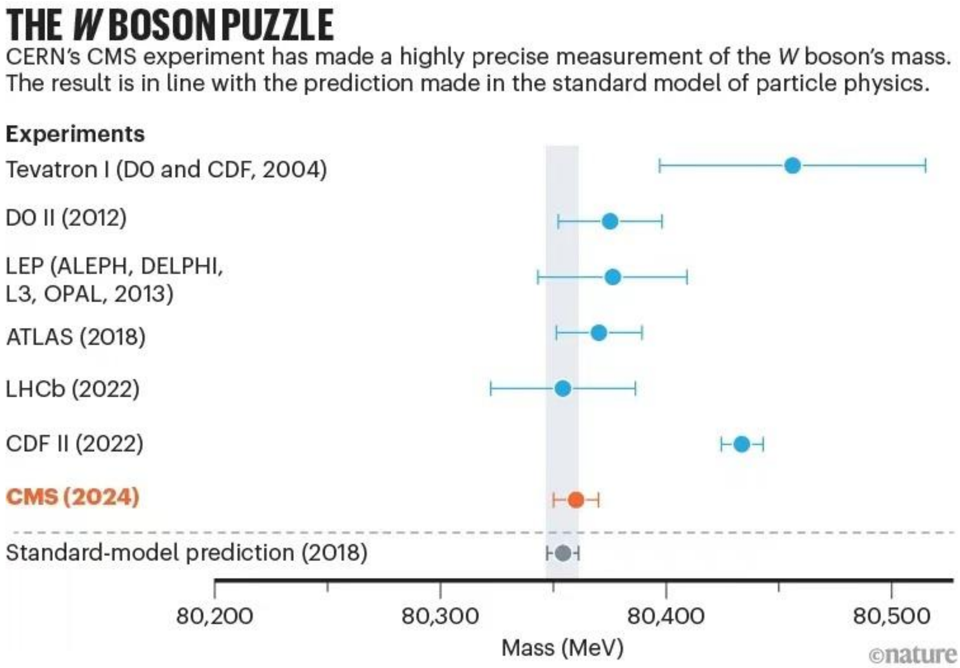

Figure 1. The puzzle of the W boson mass

from Nature 633, 745-746 (2024)

We also revised our previous formulas and calculations for the Z boson mass and Higgs boson mass along with formulas for square root of the ratio of the Z boson mass to the W boson mass which is an important parameter in Standard Model. The factors in our formulas are interesting and meaningful, so our formulas and calculations would be correct and precise.

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