Determination of the Masses of the W and Z Bosons

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Abstract

In our previous papers, we gave formulas of the fine-structure constant and their corresponding applications along with a model for the masses of elementary particles. And in recent papers, we redefined Hartree atomic units to Hartree-Chen atomic units and gave formulas which determined the precise value of the Higgs boson mass. In this paper, we apply our mass model of elementary particles and Hartree-Chen atomic units to determine the exact values of the masses of the W and Z bosons. Based on our hypothetical formulas, the masses of the W and Z bosons in Hartree-Chen atomic units should be 157415.999881172 and 178449.921171171 respectively, and the exact values of the masses of W and Z bosons should be 80439.410424(24) MeV and 91187.722114(27) MeV respectively. Compared to the latest and most accurate values of 80433.5(9.4) MeV and 91187.6(2.1) MeV which were measured by the Detector Collider at Fermilab (CDF) collaboration and Large Electron-Positron Collider (LEP) respectively, our calculated values are almost absolutely precise if they are correct.

Keywords: masses, the W Boson, the Z boson, atomic units.

1. Introduction

The W and Z bosons are carrier particles that mediate the weak nuclear force, much as photons and gluons are the carrier particles for the electromagnetic force and the strong interaction respectively. These bosons are among the heavyweights of elementary particles. With masses of 80.4 GeV and 91.2 GeV respectively, the W and Z bosons are almost 80 times as massive as the proton – heavier, even, than entire iron atoms. Their high masses limit the weak interaction to a very short range [1].

Before 2022, measurements of the W boson mass appeared to be consistent with the Standard Model. For example, in 2018, experimental measurements of the W boson mass were assessed to converge around 80379(12) MeV [1, 2]. However, in April 2022, a new analysis of data that was obtained by the Fermilab Tevatron collider before its closure in 2011 determined the mass of the W boson to be 80433(9) MeV [1, 3, 4], which is seven standard deviations above that predicted by the Standard Model.

Compared to the complicated situations in the measurements of the W boson mass, the measurements of the Z boson mass are more steady and more accurate, the latest measurements determined the Z boson mass to be 91187.6(2.1) MeV [1, 2].

In our previous papers, we gave formulas of the fine-structure constant and their corresponding applications [5-15] along with a model for the masses of elementary particles [16]. In recent papers [17-19], we defined the natural number axis (NNA) and redefined Hartree atomic units to Hartree-Chen atomic units. In another recent paper [20], we had applied our mass model of elementary particles and Hartree-Chen atomic units to determine the mass of the Higgs boson to be 125.33782309(4) GeV. In this paper, we use the same methods to determine the masses of the W and Z bosons.

2. Determination of the W Boson Mass

Based on our mass model of elementary particles [16], we constructed the following formulas of the W boson mass in Hartree-Chen atomic units (au) [19]. It is also supposed that the number factors in the formulas are meaningful and related to nuclides.

Hartree-Chen Atomic Units (au):

$$\hbar_{au} = e_{au} = a_{0/au} = 1$$

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

$$\hbar_{au} = \frac{h_{au}}{(2\pi)_{au}} = 1,\ \ h_{au} = (2\pi)_{au} = \frac{4\times 157}{100} = 6.28$$

$$c_{au} = \frac{c}{v_e} = \sqrt{112\times(168 - \frac{1}{3} + \frac{1}{12\cdot 47} - \frac{1}{14\cdot 112\cdot(2\cdot 173+1)})} = 137.035999074626$$

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

Electron mass: $m_e = 0.51099895000(15)\ \text{MeV}$

the measured mass of the W boson (2018): $m_W = 80379(12)\ \text{MeV}$

the measured mass of the W boson (2022): $m_W = 80433.5(9.4)\ \text{MeV}$

The mass ratio of the W boson to electron:

$$\beta_{W/e} = \frac{m_W}{m_e} = \frac{80433.5(9.4)\times 10^3}{0.51099895000(15)} = 157404(18)\ (157386-157423)$$

$$m_{W/au} = \frac{m_W}{m_e/(1+1/c_{au}{}^4)} = ?$$

$$m_{W/au} = \frac{m_W}{m_e/(1+1/c_{au}{}^4)} = [20(20-\frac{1}{6}+\frac{1}{6\cdot 37-\frac{4}{17}})]^2 = [20(20-\frac{1}{6}+\frac{1}{13\cdot 17+\frac{13}{17}})]^2$$

$$=157415.999881172$$

$$m_{W/au} = 8\cdot 3\cdot 7\cdot(2\cdot 7\cdot 67-1)-\frac{1}{9\cdot 5\cdot 11\cdot 17+\frac{13}{25}} = 8\cdot 3\cdot 7\cdot(8\cdot 9\cdot 13+1)-\frac{1}{9\cdot 5\cdot 11\cdot 17+\frac{13}{25}}$$

$$=157415.999881172$$

Relationships with the nuclides:

${}^{27}_{13}Al_{14}$ ${}^{28,29,30}_{14}Si_{14,15,16}$ ${}^{35,37}_{17}Cl_{18,20}$ ${}^{40}_{20}Ca_{20}$ ${}^{45}_{21}Sc_{24}$ ${}^{55}_{25}Mn_{30}$ ${}^{54,56,58}_{26}Fe_{28,30,32}$ ${}^{60,61,62,64}_{28}Ni_{32,33,34,36}$
${}^{64,66,67,68}_{30}Zn_{34,36,37,38}$ ${}^{75}_{33}As_{42}$ ${}^{85,87}_{37}Rb_{48,50}$ ${}^{98,99,100}_{44}Ru_{54,55,56}$ ${}^{112}_{48}Cd_{64}$ ${}^{9\cdot 13,118}_{50}Sn_{67,68}$ ${}^{125,126}_{52}Te_{73,74}$
${}^{9\cdot 17}_{55}Cs_{6\cdot 13}$ ${}^{136,137,138}_{56}Ba_{80,81,82}$ ${}^{15\cdot 11}_{67}Ho_{98}$ ${}^{166,168}_{68}Er_{99,100}$ ${}^{5\cdot 37,11\cdot 17}_{75}\text{Re}_{110,112}$ ${}^{188}_{76}Os_{112}$ ${}^{208}_{82}Pb_{126}$ ${}^{209}_{83}Bi^{*}_{126}$
${}^{209}_{84}Po^{*}_{125}$ ${}^{210}_{85}At^{*}_{125}$ ${}^{6\cdot 37}_{86}Rn^{*}_{8\cdot 17}$ ${}^{223}_{87}Fr^{*}_{136}$ ${}^{276}_{108}Hs^{*}_{168}$ ${}^{285}_{112}Cn^{*}_{173}$ ${}^{24\cdot 13}_{125}Ch^{ie}_{11\cdot 17}$ ${}^{314}_{126}Ch^{ie}_{188}$ ${}^{344,2\cdot 173,348}_{136,137,138}Fy^{ie}_{208,209,210}$

So the mass of the W boson should be:

$$m_W = m_{W/au}\frac{m_e}{1+1/c_{au}{}^4} = 157415.999881172\times\frac{0.51099895000(15)}{1+1/137.037999074626^4}$$

$$=80439.410424(24)\ \text{MeV}$$

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If a W boson became a photon, what would be its frequency in Hartree-Chen atomic units (au)?

$$h_{au}\nu_{W/au} = m_{W/au}c_{au}{}^2$$

$$\nu_{W/au} = \frac{m_{W/au}c_{au}{}^2}{h_{au}} = \frac{157415.999881172\times 137.035999074626^2}{6.28} = 470715576$$

$$\nu_{W/au} = 8\cdot 3\cdot 19\cdot 83[2\cdot 9\cdot(4\cdot 173-1)-1] = 8\cdot 3\cdot 19\cdot 83[2\cdot 9\cdot(2\cdot 3\cdot 5\cdot 23+1)-1]$$

$$=470715576$$

Relationships with the nuclides:

${}^{56,57,58}_{26}Fe_{30,31,32}$ ${}^{66,68}_{30}Zn_{36,38}$ ${}^{69,71}_{31}Ga_{38,40}$ ${}^{82,83,84}_{36}Kr_{46,47,48}$ ${}^{88}_{38}Sr_{50}$ ${}^{102,104,106}_{46}Pd_{56,58,60}$ ${}^{126,128}_{52}Te_{74,76}$
${}^{136,137,138}_{56}Ba_{80,81,82}$ ${}^{138}_{57}La_{81}$ ${}^{140,142}_{58}Ce_{82,84}$ ${}^{169}_{69}Tm_{100}$ ${}^{173}_{70}Yb_{103}$ ${}^{188,190}_{76}Os_{112,114}$ ${}^{11\cdot 19}_{83}Bi^{*}_{126}$ ${}^{11\cdot 19}_{84}Po^{*}_{125}$
${}^{223}_{87}Fr^{*}_{136}$ ${}^{226}_{88}Ra^{*}_{138}$ ${}^{257}_{100}Fm^{*}_{157}$ ${}^{24\cdot 11}_{103}Lr^{*}_{7\cdot 23}$ ${}^{15\cdot 19}_{112}Cn^{*}_{173}$ ${}^{2\cdot 157}_{126}Ch^{ie}_{188}$ ${}^{344,2\cdot 173,348}_{136,137,138}Fy^{ie}_{208,11\cdot 19,210}$ ${}^{19\cdot 23}_{173}Ch^{ie}_{24\cdot 11}$

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This frequency ($\nu_{W/au}$) could be called the characteristic frequency of the W boson in atomic units. It is notable that $\nu_{W/au}$ is miraculously an integer number. It means that in the atomic unit time ($t_{au} = 2.4188843265857(47) \times 10^{-17}$ s [15]) the photon corresponding to the W boson would vibrate integer multiple times exactly (470715576). This amazing coincidence should be a very strong proof to our formulas and the value of the W boson mass because of the Sagan Standard "extraordinary claims require extraordinary evidence", and it could be explained in analogy with Chinese poetry as follows.

1. W boson is analogous to Chinese characters 2. Atomic units is analogous to poetry which should be the most refined form of a language.	⇔	七绝·早发白帝城（唐·李白） 朝辞白帝彩云间，千里江陵一日还。 两岸猿声啼不住，轻舟已过万重山。

3. Determination of the Z Boson Mass

Based on our mass model of elementary particles [16], we constructed the following formulas of the W boson mass in Hartree-Chen atomic units (au) [19]. It is also supposed that the number factors in the formulas are meaningful and related to nuclides.

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

the measured mass of the Z boson (2018)：$m_Z = 91187.6(2.1)$ MeV

The mass ratio of the Z boson to electron:

$$\beta_{Z/e} = \frac{m_Z}{m_e} = \frac{91187.6(2.1)\times 10^3}{0.51099895000(15)} = 178450(4)\ (178446 - 178454)$$

$$m_{Z/au} = \frac{m_Z}{m_e/(1+1/c_{au}{}^4)} = ?$$

$$m_{Z/au} = \frac{m_Z}{m_e/(1+1/c_{au}{}^4)} = [20(22-1+\frac{1}{8}-\frac{1}{300+\frac{1}{2\cdot 3(2\cdot 3\cdot 3\cdot 29-1)}})]^2$$

$$= 178449.921171171$$

$$m_{Z/au} = \frac{m_Z}{m_e/(1+1/c_{au}{}^4)} = 2\cdot 25\cdot 43\cdot 83 - \frac{1}{12} + \frac{1}{2\cdot 3\cdot 37}$$

$$= 178449.921171171$$

Relationships with the nuclides:

$^{35,37}_{17}Cl_{18,20}$ $^{40,42,43}_{20}Ca_{20,22,23}$ $^{46,47,48,50}_{22}Ti_{24,25,26,28}$ $^{55}_{25}Mn_{30}$ $^{56,58}_{26}Fe_{30,32}$ $^{63,65}_{29}Cu_{34,36}$

$^{66,67}_{30}Zn_{36,37}$ $^{83}_{36}Kr_{47}$ $^{85,3\cdot 29}_{37}Rb_{48,50}$ $^{98,99}_{43}Tc^{*}_{55,56}$ $^{116,120}_{50}Sn_{66,70}$ $^{126}_{52}Te_{2\cdot 37}$ $^{140,142}_{58}Ce_{82,84}$

$^{136,137,138}_{56}Ba_{80,81,82}$ $^{166,167}_{68}Er_{98,99}$ $^{180,181}_{73}Ta_{107,108}$ $^{184,186}_{74}W_{110,112}$ $^{200}_{80}Hg_{120}$ $^{209}_{83}Bi^{*}_{126}$

$^{6\cdot 37}_{86}Rn^{*}_{136}$ $^{223,224}_{87}Fr^{*}_{136,137}$ $^{273}_{107}Bh^{*}_{166}$ $^{300}_{120}Ch^{ie}_{180}$ $^{2\cdot 157}_{126}Ch^{ie}_{188}$ $^{8\cdot 43,2\cdot 173,12\cdot 29}_{136,137,138}Fy^{ie}_{208,209,210}$

So the mass of the Z boson should be:

$$m_Z = m_{Z/au}\frac{m_e}{1+1/c_{au}{}^4} = 178449.921171171 \times \frac{0.51099895000(15)}{1+1/137.037999074626^4}$$
$$= 91187.722114(27)\ \text{MeV}$$

2022/7/9, 2023/1/28–29

If a Z boson became a photon, what would be its frequency in Hartree-Chen atomic units (au)?

$$h_{au}\nu_{Z/au} = m_{Z/au}c_{au}{}^2$$
$$\nu_{Z/au} = \frac{m_{Z/au}c_{au}{}^2}{h_{au}} = \frac{178449.921171171 \times 137.035999074626^2}{6.28}$$
$$= 533612577.467664$$
$$\nu_{Z/au} = 3\cdot[2\cdot 3\cdot 11(8\cdot 9\cdot 5-1)(2\cdot 27\cdot 139+1)+1]+\frac{1}{2}-\frac{1}{30}+\frac{1}{17\cdot 59}$$
$$= 533612577.467664$$

Relationships with the nuclides:

${}^{16,17,18}_{8}O_{8,9,10}$ ${}^{19}_{9}F_{10}$ ${}^{23}_{11}Na_{12}$ ${}^{32,33,34,36}_{16}S_{16,17,18,20}$ ${}^{35,37}_{17}Cl_{18,20}$ ${}^{46,48,49}_{22}Ti_{24,26,27}$ ${}^{59}_{27}Co_{32}$ ${}^{66}_{30}Zn_{36}$

${}^{82,84}_{36}Kr_{46,48}$ ${}^{105}_{46}Pd_{59}$ ${}^{113,115}_{49}In_{64,66}$ ${}^{138,139}_{57}La_{81,82}$ ${}^{138,140}_{58}Ce_{80,82}$ ${}^{141}_{59}\mathrm{Pr}_{82}$ ${}^{2\cdot 81}_{66}Dy_{96}$ ${}^{2\cdot 139}_{109}Mt^{*}_{169}$

2023/1/28–29

4. Comparison and Analysis of the Measurements of the W Boson Mass

Because the Standard Model (SM) of particle physics places tight constraints on the W boson mass, measuring the mass provides a stringent test of the model. So far, there have been a number of measurements of the W boson mass， which are listed in Table 1 in comparison with the SM expectation [3] and our calculations. Our calculation is much consistent with the average of the "more than average" values of the measurements. If our calculation is correct, there would be some systematic errors in the "less than average" values of the measurements.

Table 1. m_W measurements, the SM expectation and our calculation.

Measurements	m_W	Uncertainty	Less than average	More than average
D0 I	80478	±83		80478
CDF I	80432	±79		80432
DELPHI	80336	±67	80336	
L3	80270	±55	80270	
OPAL	80415	±52		80415
ALEPH	80440	±51		80440
D0 II	80376	±23	80376	

ATLAS	80370	±19	80370	
CDF II	80433	±9		80433
Average	80394.4		80338	80439.6

Note: 1. The SM expectation of m_W = 80357(6) MeV;

2. Our calculation of m_W = 80439.410424(24) MeV.

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Appendix I: Research and Writing History

Section	Page	Writing Period	Location	Version
Whole paper	1-6	2023/1/29-31	Shanghai	viXra:2301.0156v1
Revise section 2 Add section 4	1-7	2023/1/31-2/4	Shanghai	viXra:2301.0156v2

Note: date was recorded according to Beijing Time.