Errata

Kodansha Blue Backs "Origins of the Universe and Matter: Understanding the Invisible World"

We will sequentially list the errata discovered after the publication.

1. Page 272, Fig. 9-3:

Add 0 to the bottom of the second plot from the top.

2. Page 272, Fig. 9-3:

second vertical axis label: “（Number of Events - bkg Number of Events）” ⇨” (Number of Events - bkg Number of Events) / GeV”.

Fig.9-3_original should read Fig.9-3_revised: (Refer to the 2 red parts in Fig.9-3_revised)

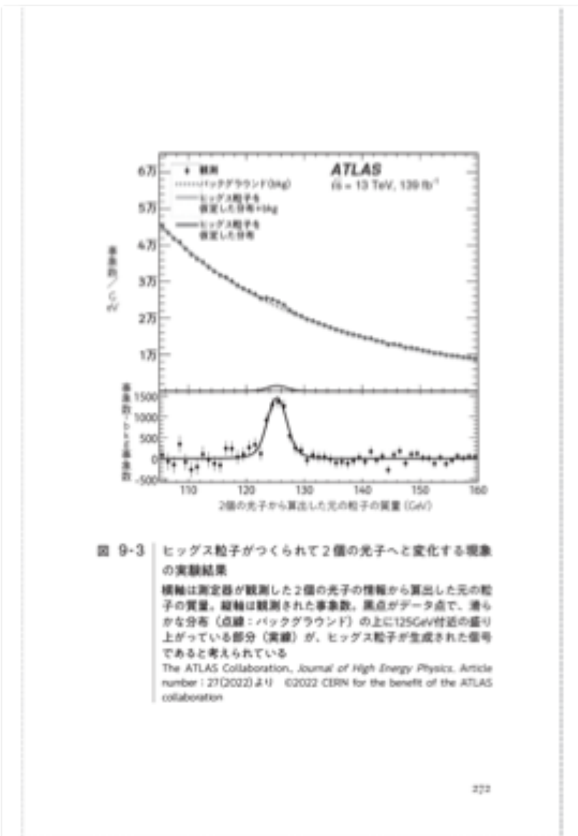

図 9-3 ヒッグス粒子がつくられて２個の光子へと変化する現象の実験結果

横軸は測定器が観測した２個の光子の情報から算出した元の粒子の質量。縦軸は観測された事象数。黒点がデータ点で、滑らかな分布（点線：バックグラウンド）の上に125GeV付近の盛り上がっている部分（実線）が、ヒッグス粒子が生成された信号であると考えられている

The ATLAS Collaboration, *Journal of High Energy Physics*, Article number : 27(2022)より ©2022 CERN for the benefit of the ATLAS collaboration

272

Fig.9-3_orignal

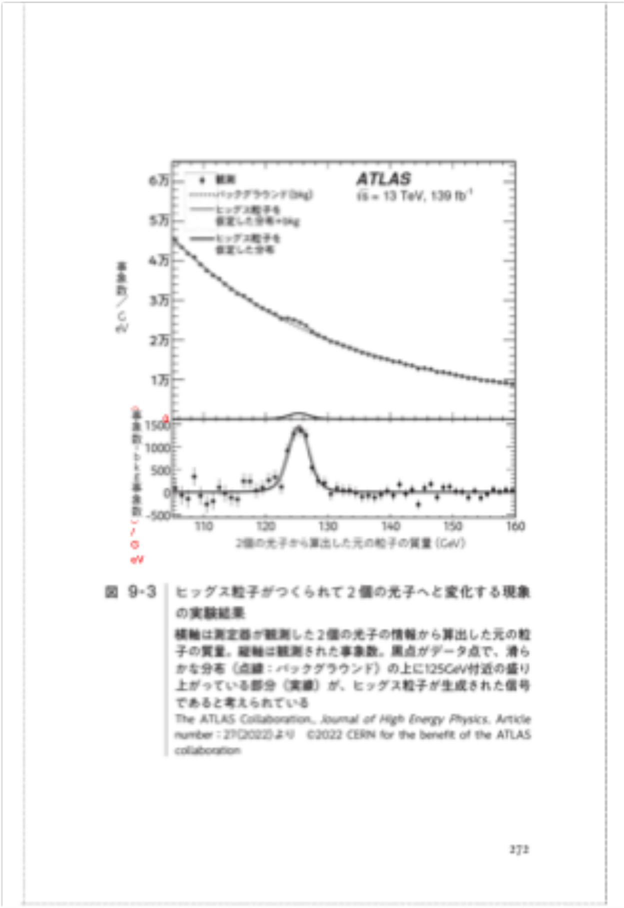

図 9-3 ヒッグス粒子がつくられて２個の光子へと変化する現象の実験結果

横軸は測定器が観測した２個の光子の情報から算出した元の粒子の質量。縦軸は観測された事象数。黒点がデータ点で、滑らかな分布（点線：バックグラウンド）の上に125GeV付近の盛り上がっている部分（実線）が、ヒッグス粒子が生成された信号であると考えられている

The ATLAS Collaboration., *Journal of High Energy Physics*, Article number：27(2022)より ©2022 CERN for the benefit of the ATLAS collaboration

272

Fig.9-3_revised

3. Page 15, Table of Contents for Chapter 3, second-to-last subheading:" Candidate celestial bodies where the r-process occurs: Supernova explosions and neutron mergers" ⇨"Candidate celestial bodies where the r-process occurs: Supernova explosions and neutron star mergers"

4. **Page 119, subheading**:

"Candidate celestial bodies where the r-process occurs: Supernova explosions and neutron mergers" ⇨ "Candidate celestial bodies where the r-process occurs: Supernova explosions and neutron star mergers"

5. Page 308, third line from the bottom:

"Error to consider, "⇨ "Considering the error," The following corrections, 6. to 18., pertain to index information.

6. Page 314, fourth line in the left column of index items:

Multiverse Hypothesis: 301 ⇨ 299

7. Page 314, 24th line in the left column of index items:

Quantum Fluctuations: 132 ⇨ 233

8. Page 315, sixth line in the right column of index items:

Non-Perturbative Limit: 292 ⇨ 290

9. Page 316, 32nd line in the left column of index items:

Dark Energy Problem: 262 ⇨ 261

10. Page 316, first line in the right column of index items:

Dark Matter: 242 ⇨ 240

11. Page 316, sixth line in the right column of index items,

Grand Unified Force: 287 ⇨ 285

12. Page 316, 22nd line in the right column of index items:

Superconducting State: 287 ⇨ 285

13. Page 316, 22nd line in the right column of index items:

Grand Unified Force: 287 ⇨ 285

14. Page 317, 23rd line in the left column of index items:

Cosmological Constant Problem: 262 ⇨ 261

15. Page 318, 16th line in the right column of index items:

J-PARK ⇨ J-PARC

16. Page 318, 22nd line in the right column of index items:

LHC (Large Hadron Collider): 272 ⇨ 270

17. Page 318, 30th line in the right column of index items:

r-process (rapid neutron capture process): 113⇨ 112

18. Page 318, 32nd line in the right column of index items:

s-process (slow neutron capture process): 113⇨ 112

19. **Page 9, second line**:

"European Organization for Nuclear Research" ⇨ "European Nuclear Research Organization"

20. Page 157, Line 1:

"and its square is,"⇨ "and the square of its absolute value, which is proportional to the probability of existence, is,"

21. Page 157, Line 2:

$z^2 = (a + ib)(a - ib) = a^2 + b^2$ ⇨ $|z|^2 = (a + ib)(a - ib) = a^2 + b^2$

22. Page 158, Line 6:

$z^2 = r^2(\cos(\theta) + i \sin(\theta))^2 = r^2(\cos^2(\theta) + \sin^2(\theta)) = r^2$ ⇨ $|z|^2 = r^2|\cos(\theta) + i \sin(\theta)|^2 = r^2(\cos^2(\theta) + \sin^2(\theta)) = r^2$

23. Page 158, Line 7:

"because z^2, which is the probability of the electron's position, does not change." ⇨ "because $|z|^2$, which is proportional to the probability of the electron's position, does not change."

24. **Page 269, Line 1**:

$\phi_1(x,y,z,t)$ ⇨ $\varphi_1(x,y,z,t)$

25. Page 269, Line 2:

$\phi_2(x,y,z,t)$ ⇨ $\varphi_2(x,y,z,t)$

26. Same Page 269, Line 2:

"the magnitude of energy, ($|\phi_1|$,$|\phi_2|$)" ⇨ "the magnitude of energy, ($|\varphi_1|$,$|\varphi_2|$)"

27. **Same Page 269, Line 4:**

"values of the field ($|\phi_1|$,$|\phi_2|$)for the complex Higgs fields ϕ_1 and ϕ_2" ⇨ "values of the field($|\varphi_1|$,$|\varphi_2|$) for the complex Higgs fields φ_1 and φ_2"

28. Page 96, Line 1:

"age of the universe is approximately one-billionth of a second" ⇨ "age of the universe is approximately one ten-billionth of a second"

29. Page 96, Line 2:

"higher than approximately 100 billion degrees" ⇨ "higher than approximately 1 trillion degrees"

30. Page 96, Line 2:

“approximately 30 cm in size. “ ➪ approximately 3 cm in size”

31. Page 187, Line 13-14 and page 188 line 1 to 7:

Let’s express "Person A borrows money from Person B" as A + (+m) = B. In this context, "Person B lends money to Person A" can be represented as A = B + (-m). Here, mm denotes the amount of money involved in the transaction. Through this interaction, Person A's amount of money increases, so it is denoted as +m, while Person B's amount decreases, represented as −m.

If we label −m as a "lending particle" and +m as a "debt particle," we can observe that, although the monetary value is the same, the interpretation changes depending on the perspective: from Person B's viewpoint, it is a "loan," while from Person A's viewpoint, it is a "debt." These perspectives are inversely related. This relationship between the "lending particle" and the "debt particle" mirrors the relationship between particles and antiparticles.

⇨

When we say, “Person A borrows *m* yen from Person B,” Person A’s amount of money increases by *m* yen, so it can be written as:

A + (+m).

On the other hand, if we express it as “Person B lends *m* yen to Person A,” then Person B’s money decreases by *m* yen, so it becomes:

B - m = B + (−m).

It’s the same situation, but in the first expression, Person A’s money increases, so it’s +m.

Meanwhile, Person B’s money decreases, so it’s −m.

Now, if we name −m the “lending particle” and +m the “borrowing particle,” these two particles have the same magnitude but represent opposite sides: from B’s point of view it’s a loan, while from A’s point of view it’s a debt.

You can see that the two are exact opposites depending on the observer’s perspective.

This relationship between the “lending particle” and the “borrowing particle” corresponds to that between a particle and an antiparticle.

32. Page 307, Line 19-21:

After completing the doctoral program (later stage) in the Graduate School of Science at Nagoya University in March 1988, the individual served as a Special Research Fellow of the Japan Society for the Promotion of Science (JSPS) at Nagoya University.

⇨

After completing the doctoral program (later stage) in the Graduate School of Science at

Nagoya University in March 1988, earning a Doctor of Science degree. Subsequently, the individual served as a Special Research Fellow of the Japan Society for the Promotion of Science (JSPS) at Nagoya University.

33. Page 48, Line 2 of the caption in Figure 1-5,

“Anderson, C.D. Physical Review 43 (1993)” ⇨
“Anderson, C.D. Physical Review Vol. 43 p.491 (1933)”

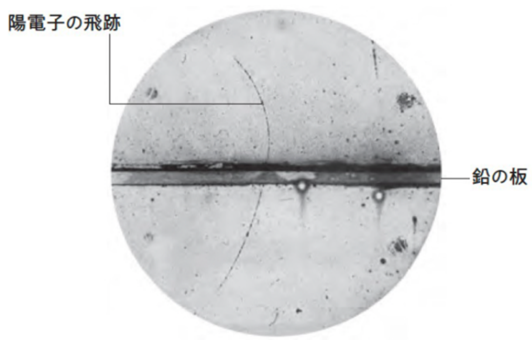

図 1-5 アンダーソン博士が霧箱を使って撮影した陽電子の飛跡
Anderson C.D., *Physical Review* ~~43 (1993)~~ より
Vol.43, p491 (1933)

34. Page 109, Line 13,

“brown dwarfs or white dwarfs.” ⇨ “white dwarfs.”

35. Page 109, in Figure 3-5,

The arrow from 'Planetary nebula' to 'brown dwarf' should be deleted.

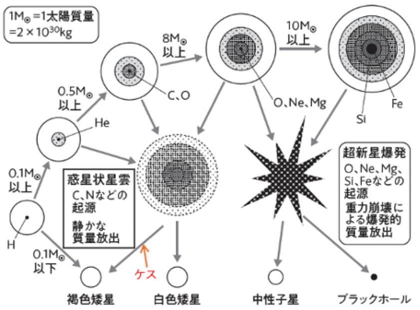

図 3-5 初期質量によって異なる「星の一生」と生成元素
星が生まれたときの質量によって、星の中でどこまで重い元素を生成できるかが変わり、寿命や終末期の姿も異なる
和南城伸也「超新星爆発におけるrプロセスとrpプロセスII」第11回TRIACセミナー（2008年7月2日）p3の図をもとに作成

36. Page 267, Line 17:

When the energy potential of the two complex Higgs fields assumed to be paired in the Standard Model is illustrated,

⇨

When the potential energy density of the two complex Higgs fields assumed to be paired in the Standard Model is illustrated,

37. **Page 267, Figure 9-1:**

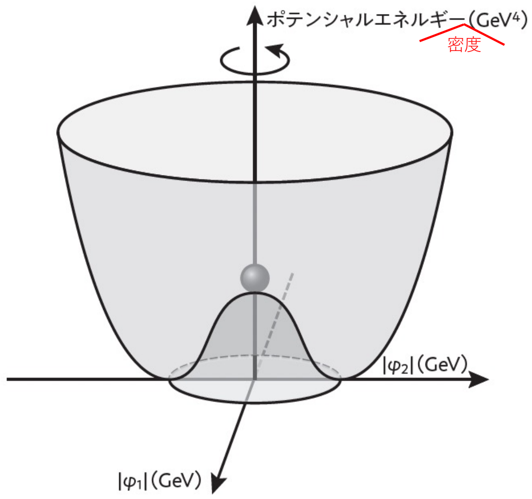

図 9-1 標準理論が想定する対になっている２つの複素ヒッグス場φ_1とφ_2に、$(|\varphi_1|,|\varphi_2|)$ という大きさを与えるために必要なポテンシャルエネルギー密度の形

しばしばワイン瓶の底の形に例えられる。中央の盛り上がったところはエネルギーが高く、しかも不安定なので、エネルギーの低い円環状になった底に落ち、そこが「真空」になる。どこに落ちるかは決まっていないため、真空には回転対称性がない。対称性が破れたことで、素粒子に質量が発生したと解釈される

268

Figure 9−1, “Higgs potential energy” ⇨ “Higgs potential energy density”

and in the caption of Figure 9−1, “the Higgs field potential energy”

⇨ “the Higgs field potential energy density”

38. **Page 269, from line 1to line5:**

It appears as shown in Figure 9–1. This figure represents the energy potential (with units of GeV[4]) required to give the Higgs fields $\varphi_1(x,y,z,t)$ and $\varphi_2(x,y,z,t)$ at position(x,y,z) and time t, an energy magnitude of ($|\varphi_1|$,$|\varphi_2|$) where the units of each component are GeV.

In Figure 9–1, the vertical axis represents the magnitude of the energy required to give the complex Higgs fields φ_1 and φ_2 the field values ($|\varphi_1|$,$|\varphi_2|$). For example, imagine placing a ball on top of the central peak in this figure.

⇨

It appears as shown in Figure 9–1. This figure represents the potential energy density (with units of GeV[4]) required to give the Higgs fields $\varphi_1(x,y,z,t)$ and $\varphi_2(x,y,z,t)$at position (x,y,z) and time t, an energy magnitude of ($|\varphi_1|$,$|\varphi_2|$), where the units of each component are GeV.

In Figure 9–1, the vertical axis represents the magnitude of the energy density required to give the complex Higgs fields $\varphi_1$and φ_2 the field values ($|\varphi_1|$,$|\varphi_2|$) . For example, imagine placing a ball on top of the central peak in this figure.

39. Page 291, line14 and line15:

$V(\phi)=\mu^2 \phi^2+\lambda\phi^4$

Here, ϕ represents the strength of the Higgs field (corresponding to the brightness of the light bulb in our analogy),

⇨

$V(\varphi)=\mu^2 \varphi^2+\lambda\varphi^4$

Here, φ represents the strength of the Higgs field (corresponding to the brightness of the light bulb in our analogy),

40. Page 292, full text:

the coefficient λ corresponds to the Higgs self-coupling constant. Despite being called "constants," μ and λ change slightly with energy. As explained in Chapter 9, the Higgs field in the Standard Model consists of two paired complex components, $\phi_1$and ϕ_2. The magnitude of the Higgs field refers to the distance from the origin in a complex two-dimensional plane composed of ϕ and ϕ given by $\phi \equiv \sqrt{|\phi_1|^2 + |\phi_2|^2}$.

The more energy is injected, the more brightly the bulb lights up, so μ and λ can be thought of as functions of the value of ϕ.

If the coefficients μ^2 and λ are both positive, the potential energy is minimized when ϕ =0, meaning the light bulb is off. However, the Standard Model assumes that λ>0 and μ^2<0, even though it offers no explanation for why this is the case. Under this assumption, the potential energy density is minimized at ϕ =v=$\sqrt{-\mu^2/(2\lambda)}$>0 meaning the Higgs field is faintly lit in the vacuum. While this assumption is convenient for fitting observations, it lacks deeper theoretical justification.

That was a slight digression. Now that we understand the relationship between the Higgs self-coupling constant λ and the potential energy density of the Higgs field V(ϕ),

⇨

the coefficient λ corresponds to the Higgs self-coupling constant. Despite being called "constants," μ and λ change slightly with energy. As explained in Chapter 9, the Higgs field in the Standard Model consists of two paired complex components, φ_1 and φ_2. The magnitude of the Higgs field refers to the distance from the origin in a complex two-dimensional plane composed of φ_1 and φ_2 given by $\varphi \equiv \sqrt{|\varphi_1|^2 + |\varphi_2|^2}$.

The more energy is injected, the more brightly the bulb lights up, so μ and λ can be thought of as functions of the value of φ.

If the coefficients μ^2 and λ are both positive, the potential energy is minimized when φ =0, meaning the light bulb is off. However, the Standard Model assumes that λ>0 and μ^2<0, even though it offers no explanation for why this is the case. Under this assumption, the potential energy density is minimized at φ=v=$\sqrt{-\mu^2/(2\lambda)}$>0 meaning the Higgs field is faintly lit in the vacuum. While this assumption is convenient for fitting observations, it lacks deeper theoretical justification.

That was a slight digression. Now that we understand the relationship between the Higgs self-coupling constant λ and the potential energy density of the Higgs field V(φ),

41.Page 293 – full text:

You may already see the issue. In this case, the larger the value of φ becomes, the more V(ϕ) can decrease without bound, eventually tending toward negative infinity. Since the vacuum energy becomes unbounded from below, the theory breaks down.

"False Vacuum" and "True Vacuum"

In reality, before the vacuum energy density V(ϕ) descends to negative infinity, the previously negligible influence of gauge particles (force carrier particles) on Higgs self-coupling becomes significant and causes λ to revert to being greater than zero. Thus, the potential energy density V(ϕ) does not reach negative infinity. Instead, a new energy minimum—representing the "true vacuum"—emerges at very large values of ϕ. On the other hand, the energy minimum assumed by the Standard Model at ϕ=v=$\sqrt{-\mu^2/(2\lambda)}$ is lower than its surroundings but still has a higher energy than that of the true vacuum. The exact location of the true vacuum is determined by the shape of V(ϕ) which in turn depends on the masses of the Higgs particle and the top quark.

Figure 10-1 illustrates how V(ϕ) changes as the mass of the top quark is varied, while the Higgs particle mass is fixed at 125 GeV. The experimental values used in this calculation are m_H=125.9±0.4GeV for the Higgs particle mass and approximately m_t=171.393GeV for the top quark mass. Zooming in near ϕ =0 reveals that the potential approximates the Standard Model's Higgs field potential when μ^2 and λ are treated as constants. This region near φ =0 corresponds to the "Standard Model vacuum".

⇨

You may already see the issue. In this case, the larger the value of φ becomes, the more V(φ) can decrease without bound, eventually tending toward negative infinity. Since the vacuum energy becomes unbounded from below, the theory breaks down.

"False Vacuum" and "True Vacuum"

In reality, before the vacuum energy density V(φ) descends to negative infinity, the previously negligible influence of gauge particles (force carrier particles) on Higgs self-coupling becomes significant and causes λ to revert to being greater than zero. Thus, the potential energy density V(φ) does not reach negative infinity. Instead, a new energy minimum—representing the "true vacuum"—emerges at very large values of φ. On the other hand, the energy minimum assumed by the Standard Model at φ=v=$\sqrt{-\mu^2/(2\lambda)}$ is lower than its surroundings but still has a higher energy than that of the true vacuum. The

exact location of the true vacuum is determined by the shape of V(φ) which in turn depends on the masses of the Higgs particle and the top quark.

Figure 10-1 illustrates how V(φ) changes as the mass of the top quark is varied, while the Higgs particle mass is fixed at 125 GeV. The experimental values used in this calculation are m_H=125.9±0.4GeV for the Higgs particle mass and approximately m_t=171.393GeV for the top quark mass. Zooming in near φ =0 reveals that the potential approximates the Standard Model's Higgs field potential when μ^2 and λ are treated as constants. This region near φ =0 corresponds to the "Standard Model vacuum".

42. Page 294 in Figure 10-1:

The vertical axis:

" Higgs field potential energy" ⇨ " Higgs field potential energy density"

43. Page 294 in the caption of Figure 10-1:

" Higgs field potential energy" ⇨ " Higgs field potential energy density"

44. Page 294, line 3rd:

"ϕ" ⇨ "φ"

45. Page 294, line 6th:

"ϕ" ⇨ "φ"

46. Page 180, 3rd line from the end :

"The mass of the Higgs particle has been measured in LHC experiments to be about 125 GeV.

Because the Higgs particle is a spin–0 particle, quantum field theory—the mathematical framework of particle physics—tells us that the Higgs mass squared receives corrections from interactions with other elementary particles proportional to the square of their masses.

In addition, a hypothetical "Grand Unified Higgs particle," which plays the role of spontaneously breaking an originally unified force into three distinct forces—electroweak U(1), electroweak $SU(2)_L$, and strong SU(3)—can also influence the mass of the 125 GeV Higgs particle. The mass of such a Grand Unified Higgs particle is expected to be extremely large, on the order of 10^{16}GeV. This means that the

125 GeV Higgs mass could, in principle, receive additional corrections proportional to the square of this enormously large mass.

However, the observed Higgs mass is in fact 125 GeV.
In other words, despite the possibility of corrections as large as 32 orders of magnitude in mass squared—up to 28 orders of magnitude larger than the observed value—some kind of mechanism must finely adjust these effects so that the Higgs mass remains at 125 GeV.
The question of what principle carries out such an extraordinary adjustment is known as the *fine-tuning problem*."

⇨

The mass of the Higgs particle has been measured in LHC experiments and is about 125 GeV. Because the Higgs particle is a spin-0 particle, according to the mathematical framework of particle physics—quantum field theory—it is understood that the mass of the Higgs particle could be affected by quantum mechanical effects from other particles that interact with the Higgs. Specifically, assuming that just after the birth of the universe the three forces—the electroweak force U(1), the electroweak force $SU(2)_L$, and the strong force SU(3)—were unified (Grand Unified), the Higgs mass would receive corrections proportional to the square of the Grand Unification energy scale, 10^{16} GeV. This is called the "higher-order mass corrections" due to quantum mechanical higher-order effects. However, the observed mass of the Higgs particle is 125 GeV.

(additional a null line)

In other words, despite the fact that the Higgs particle could, in principle, receive a "higher-order mass corrections" as large as 28 orders of magnitude—obtained by subtracting 4 digits (corresponding to 125^2) from 32 digits (corresponding to $(10^{16})^2$)—some form of adjustment is at work, keeping the Higgs particle's mass at 125 GeV. The question of what principle is responsible for such a fine adjustment across such a huge number of orders of magnitude is what is known as the *fine-tuning problem*.

47. Page 181, 5th line from the end :

Two possible approaches can be considered to solve this fine–tuning problem. This problem arises from the fact that the Higgs particle has spin 0. For particles with spin 1/2 or spin 1, it is known that changes to their masses are not proportional to the square of the interacting particle's mass, and their effects are therefore suppressed.

⇨

Two possible approaches can be considered to solve this fine–tuning problem. This problem arises from the fact that the Higgs particle has spin 0. According to quantum field theory, for particles with spin 1/2 or spin 1, the change in mass due to quantum mechanical effects from particles with which they interact does not increase proportionally to the square of the energy scale but is known to grow only logarithmically.

Sept. 25th 2025
IPNS, KEK