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Abstract

This essay summarizes the basic conceptions constructed with the development of particle collider since 1920s. The major data parameters of decay pathways in element particles detected by particle collider have been described, including exited state and background state, resonance, branch ratio, scattering cross section, based on which the case studies published in China have been reviewed subsequently. Finally my original viewpoints have been discussed to initiate the future study.

Key words: Particle Collider, Element Particles, Exited State, Resonance, Branch Ratio, Scattering Cross Section.

Introduction

With the development of particle collider in human history, the discovery of micro particles inside atom achieves qualitative understanding, and the elementary particles are partitioned into finer and finer scales as classification of particles inside atom. This essay reviews the relevant conceptions and case studies published in China firstly, and subsequently aims to change the quantum research focus into new materials synthesizing instead of finer particle discovery on radioactive materials.

1.Particle Collider Mechanism and Structure

The main function of particle collider is to accumulate and accelerate the two particle streams successively injected by the previous accelerator, which makes them collide when both of them reach sufficient levels in intensity and energy, so as to produce amplified reaction energy. The types of particle collisions include selective positron-electron collision, hadron collision, proton collision and elementary particle collision, etc. The objectives of this particle collider experiment is to test the material characteristics of experimental instruments, to explore the macro effects of micro particles, and to understand the new natural laws of quantum physics in micro-particles[1].

The characteristics of the particle collider are very similar to the synchrotron: The particle collider is in a ring, along which magnet system, high frequency system, vacuum system, detection and correction system are installed. In addition, it also has two or more special long linear sections for particle collision along the ring, integrated by the detection instrument placed in the space near the collision point in the long linear section. For the collision between the opposite electric-charged particles with the same static mass, it is relatively simple for two beams of particles to collide inside the particle collider as one ring is established. However, if the particles with the same charge and mass collide, two rings must be required, with the opposite directions of the applied magnetic field between the two rings. Accumulation, acceleration and collision become the three major functions of the collider. The accumulation function is to accumulate the pulsed particle beams accelerated by the high-energy accelerator at different times in the annular vacuum chamber (called storage ring) of the collider. Generally, dozens or thousands of bundles need to be accumulated in order to achieve the intensity required for collision[1].

The accumulation of electron beams is achieved by electron synchrotron radiation. Although electron synchrotron radiation makes it difficult to further strengthen the energy of synchrotron, it leads both transverse and longitudinal dimensions of electron beam to shrink greatly in the acceleration process, which significantly increases the density. In comparison, protons do not show this characteristic, which requires the momentum accumulation process to obtain the proton beams at high energy level[1].

After accumulating momentum, the collider can further accelerate the high-energy particles injected, which functions exactly the same as an ordinary synchrotron. The energy of the particles is supplied by the high-frequency acceleration cavity arranged on the ring. During the whole acceleration process, the magnetic field of the collider gradually rises, in which the frequency of the high-frequency cavity is also risen with the integral multiple frequency of accelerated cyclotron particles, continuously accelerating to higher energy [1].

When the particle beams are accelerated to the predefined level of energy, the magnetic field of the collider is maintained at the correspondingly constant value, and the particle beam rotates continuously in the annular vacuum chamber. Subsequently the two beams collide at a certain point in the collision region, when the measuring instruments arranged around the collision area can continuously measure the events during the collision. The remaining un-reacted particles continue to gyrate in the ring and collide again when they reach the collision area next time. Until the intensity of the beam is reduced so that the physical experiments can no longer be carried out, the life of the two beams is terminated in this experiment[1].

2.Radioactive Materials

Radioactive materials are those that naturally radiate energy and emit rays. Generally, radioactive materials include metals with high atomic mass, such as plutonium, uranium, etc. There are generally three kinds of radiation emitted by radioactive materials, including α Ray, β Ray, and γ Ray [2]. Radioactive decay is a process in which radioactive elements spontaneously release radiation and energy, finally converting into other stable elements. Radioactive decay takes a certain period or life circle and is generally stable regardless of environmental changes, which is consequently used to determine the age of chemistry substances.The decay of an atom generates another element and releases α Particles, β Particles or neutrino, so the sum of the static mass of the physical particles after decay will be less than the sum of the static mass of the physical particles before decay [3].

3.Radioactive Particles

α Particles are the particles emitted when some radioactive materials decay, which are composed of two neutrons and two protons (He nucleus). The mass of α Particles is four times that of hydrogen atoms, with the speed reaching 20000 kilometers per second. However, α Particles transmission leads to weak penetration capacity but can hurt animal skin. α Particle is a positively charged high-energy particle that loses energy rapidly after passing through a medium [4].

In the process of β decay, the radioactive nucleus is transformed into another stable form of nucleus by emitting electrons and neutrinos. The electrons emitted are called β Particles, which can be classified into positive and negative β decay. In the positive β decay, a proton in the nucleus is transformed into a neutron, and a positron is released as positive β Particle at the same time, whereas in negative β decay, a neutron in the nucleus is transformed into a proton and an electron is released as β Particle at the same time. β Particles are high-speed electrons, and its transmission is affected by electromagnetic fields. The β particles are much finer (only 1 / 8000 of α particles) and have greater penetration capacity than α particle, so that it needs an aluminum sheet of a few millimeters thickness to intercept it. β Particles are the elementary particle composed of β ray beams with the current of electrons or positrons [5].

4.Basic Particle Classification

Classification of basic particles in atom varies. One of the representative classification is that the elementary particles are classified into finer scales with static mass: there are 12 kinds of basic particles constituting the material world, including 6 kinds of quarks which are further classified into upper, lower, odd, charm, bottom and top, with three colors per quark as well as the anti quark of each quark, 3 kinds of charged leptons (electrons, μ lepton, τ lepton with its corresponding antimatter per lepton), and 3 kinds of neutrinos (electron neutrinos, μ Neutrinos and τ Neutrinos with its corresponding antimatter per neutrino) [6]. There are also other particles acting as the interactive medium, including quantum photons, gluons, Gauge boson [7].

5.Elementary Characteristics of Particles

Size: the size of protons and neutrons is only 1/100 000 of atoms, but leptons and quarks are much smaller, less than 1/100 000 of protons and neutrons [7].

Mass: quantum photons and gluons have no static mass, and the electron mass is very small. The mass of π meson is 280 times that of electron, and protons and neutrons are more heavy, approximately 2000 times than the mass of electrons. The heaviest quark known is the top quark. There are six kinds of quarks have been found from lower quark to top quark, with light to heavy mass. The mass of neutrinos is very small, with the measured mass of electronic neutrinos at 1/70000 of electron mass [7].

Lifetime: the lifetime of particles is one of the main characteristics. Electrons, protons and neutrinos are the stable ones as 'long-lived' particles, whereas most of other particles are unstable, which decay in their lifetime. For example, a free neutron decays into a proton, an electron and a neutrino; a π pion decays into a μ particle and a neutrino. The lifetime of a particle is defined by the time span when the intensity decays to half [7].

Symmetry: there is the symmetry between particles. If there is a particle, there must be an anti-matter. When a pair of positive and negative particles collide, they can annihilate and become quantum photons carrying energy, which means that the particle mass can be transformed into energy; On the contrary, when two high-energy particles collide, they may produce a pair of new positive and negative particles, which means that energy can also be transformed into the mass of particles [7].

Spinning: spin/rotation is one of the attributes in particles. Particles with semi-integer spinning are called fermions, and those with integer spin are called bosons [7].

Wave particle duality：particles in the micro world have dual properties: particle and volatility [7].

6.Excited State and Ground State

After an atom or molecule absorbs a certain amount of energy, the electron is excited to the higher energy level without reaching ionized state. When the atom or molecule is under the excited state, the distribution of electron cloud changes, so that the distance between molecular nuclei equilibrium increases, and the chemical reaction activity increases. Under the interaction with ionizing radiation (or electromagnetic radiation), if the energy transferred to the atom or molecule is lower than its ionization potential but is enough to make the electron transition to the higher energy level, the atom or molecule is under the excited state[8].

In comparison, the ground state refers to the stationary state, under which the atom is at the lowest energy level and the electron normally moves along the orbit closest to the nucleus[9].

7.Resonance

Resonance is a type of particle state for particle hadrons. Resonance is found in the atomic research of nuclear scattering and reaction process. When the incident particle reaches to the threshold energy level, the cross section of particle scattering increases rapidly, which is consistent with the resonance phenomenon in physics. According to the analysis of quantum mechanics, it is shown that this resonance phenomenon occurs when the incident particles and atomic nuclei combine to form into metastable composite nucleus, which subsequently decays into the final stable particles in a period. This metastable composite nucleus as the combination of incident particles and nuclei is called the resonant state[10].

8.Branching Ratio

The original nucleus usually decays into the final particles through different pathways (branches), and the probability in each pathway (branch) is called branching ratio. For example, the nuclide radium-226 can decay into radon-222 in several pathways. Because radon has several excited states, when radium-226 decays into different excited states of nucleus, it release different α particles at corresponding energy levels. There are two major kinds of decay branches for nuclide radium-226: one is that it emits α particle with energy of 4.598 Mev, decaying to an excited state of the radon-222 which further emits an energy of 0.186 Mev γ photons, and finally it decays into the ground state of radon. The probability of this decay pathway is 5.4%; The other decay branch is radium emitting an α particle with the energy of 4.784 Mev, finally decaying directly to the ground state of radon-222, and the probability of this decay branch is 94.6%[11].

9.Scattering Cross Section

Scattering cross section is a physical parameter that describes the scattering probability of micro particles, also known as collision section. When a moving particle collides with another stationary particle, if the number of moving particles per unit area perpendicular to the moving direction in unit time is 1 and the number of stationary particles is also 1, the probability of collision per unit time is called collision cross section[12].

10.Case Studies in China

The main studies published in China sources from the event data collected by the BESIII collider in Beijing China. Other studies based on different colliders include LHeC and VEPP-2000 collider, which is also published in China and reviewed in this essay:

10.1. Zhang (2016) conducted the quantum research on Baryon spectroscopy in Beijing, which measured the structure of hadrons and its corresponding decay pathways. According to the 4.48×10^{8} Ψ (3638) events detected by BESIII instrument at BEPCII, it is the first time to measure the decay pathway $\Psi(3638) \rightarrow \Lambda\bar{\Lambda}\omega$, with branching ratio of $(3.42 \pm 0.34(\mathit{stat.}) \pm 0.31(\mathit{syst.})) \times 10^{-5}$. The exited state of particle Λ* is measured as 2.001 ± 0.007 GeV and 0.036 ± 0.014 GeV (significance 3.3σ) for the mass and width respectively. For the decay pathway $\Psi(3638) \rightarrow \Lambda\bar{\Lambda}^{*}/\ \bar{\Lambda}\Lambda^{*} \rightarrow$

$\Lambda\bar{\Lambda}\omega$, the measured branching ratio is 1.93 × 10^{-5} (Confidence level at 90%)[13].

Another 1.31×10^9 events detected by BESIII instrument in 2009 and 2012 for decay pathway of J/Ψ → $\Lambda\bar{\Lambda}\eta$ is analyzed. The branching ratio of this decay pathway is (19.93 ± 0.38(*stat.*) ± 0.14(*syst.*)) × 10^{-5}. However, this decay pathway are further divided into sub-pathway: J/Ψ → Φ(2170)η → $\Lambda\bar{\Lambda}\eta$ and J/Ψ → X(2239)η → $\Lambda\bar{\Lambda}\eta$, with the upper limit of branching ration at 2.29×10^{-6} and 3.31×10^{-6}, respectively[13].

10.2. According to the annihilation data φ(3770) produced by the collision between negative electrons and positive positrons (e^-e^+) detected by BESIII instrument in Beijing, there are there decay pathways found in hadron of D+ singly Cabibbo-suppressed: $D^+\rightarrow\eta\pi0\pi+$;$D^+\rightarrow\eta\eta\pi+$; $D^0 \rightarrow \eta\pi\text{-}\pi+$. Each branching ratio is calculated as[14]:

$B(D^+\rightarrow\eta\pi0\pi^+)$=(2.23 ± 0.15(*stat.*) ± 0.13(*syst.*))× 10^{-3};
$B(D^+\rightarrow \eta\eta\pi^+)$=(2.96 ± 0.24(*stat.*) ± 0.13(*syst.*))× 10^{-3};
$B(D^0 \rightarrow \eta\pi^-\pi^+)$=(1.18 ± 0.07(*stat.*) ± 0.04(*syst.*))× 10^{-3};

The signal of hadron D+ shows statistic significance at 10σ in each decay pathway[14].

10.3. Based on the experimental data detected by the Beijing Spectrometer on the Beijing positron-electron collider, which spans energy range from 2.050 to 3.080 GeV, it is to study the decay channel of Y (2175) through two pathways: e + e^- → Φ η’ and e + e^- → K + k-Φ by Sun (2019) [15].

For the measurement of cross section in the e + e^- → Φ η’ pathway, the resonant signal with significance of more than 12σ is observed near the energy level at 2.180 GeV. The parameters of resonant central mass and width are measured to be m = (2182.4 ± 5.1(*stat.*) ± 1.6(*syst.*)) MeV / C^2 and r = (142.2 ± 16.6(*stat.*) ± 0.0(*syst.*)) MeV, respectively. Additionally, the cross section in the e+e-ΦK+K- pathway is also measured in this study by comparison and contrast with other research findings [15].

10.4. According to the 447.9 × 10^6 events in total of ψ(2S) by BESIII detector, *hc* decaying to 3 (π+π-) through pathway $\psi(2S)\rightarrow\pi^0$hc is studied by Ban (2020) [16]. There is not evident *hc* signal detected in the invariant mass spectrum of 3 (π+π-). At 90% confidence level, the branching ratio of *hc* → 3 (π+π-) process at upper limit is measured to be B < 2.89×10^{-3}. According to the 10×10^9 events of J/ψ, it is found that the asymmetric X(1840) resonance exists in the invariant mass spectrum of 3 (π+π-) in decay pathway $J/\psi\rightarrow\gamma^3$(π+π-). The mass, width and branching ratio of X(1840) are measured to be 1823.6 ± 2.5(*stat.*) ± 0.5(*syst.*), 94.0 ± 8.9(*stat.*) ± 25.7(*syst.*) and (1.76

± 0.07(*stat.*) ± 0.59(*syst.*)) × 10^{-5} respectively. In comparison, the corresponding parameters of X (1880) are reported as 1880.6 ± 1.6(*stat.*) ± 2.5(*syst.*), 39.8 ± 4.6(*stat.*) ± 7.5(*syst.*) and (0.94 ± 0.03(*stat.*) ± 0.25(*syst.*)) × 10^{-5} respectively [16].

10.5. BESIII detector collects 4.5×10^{8} events of Ψ(3686), which is studied by Wang (2021)[17]. The decay pathway of Ψ(3686) → $\overline{\Sigma}^{0}\Lambda$ + *c.c.* is considered as iso-spin violating mode, and its branching ratio is calculated as (1.60 ± 0.31(*stat.*) ± 0.13(*syst.*) ± 0.58(*syst.+inter.*)) × 10^{-6}. According to events of Ψ(3686), the decaying pathways of $\chi_{cJ} \to \Lambda\overline{\Lambda}$ are further divided into three sub-pathways: $\chi_{c0} \to \Lambda\overline{\Lambda}$; $\chi_{c1} \to \Lambda\overline{\Lambda}$; $\chi_{c2} \to \Lambda\overline{\Lambda}$. The branching ratio of each sub-pathway is measured as (3.64 ± 0.10(*stat.*) ± 0.10(*syst.*) ± 0.07)× 10^{-4}, (1.31 ± 0.06(*stat.*) ± 0.06(*syst.*) ± 0.03) × 10^{-4}, (1.91 ± 0.08(*stat.*) ± 0.17 (*syst.*)± 0.04)×10^{-4}, respectively, where the third inaccuracy is the crossing one by the inaccuracy of $\gamma\chi_{cJ} \to \Lambda\overline{\Lambda}$ branching ratio[17].

10.6. BESIII collider detects the $e^+e^- \to \omega\eta$ decay process under the parameter centroid energy $\sqrt{S}$ ranging from 3.686 to 4.700 GeV in Pei (2021) study[20]. The BORN cross section of this decay pathway is calculated according to the reconstruction of particle state ω and η, which is further incorporated into Breit-Winger function interpreting the resonance states. However, there is no significant signals reported to prove the decay mode of Y(4360) → ωη in this study[20].

10.7. According to the e^+e^- collision data detected by BESIII instrument under the parameters of collision energy level $\sqrt{S}$ = 4.180 GeV and luminosity at 3.19 fb^{-1}, the decay pathway of hadron D_s → PP is studied by Li (2019)[22]. There are three statistic modes calculated in the decay pathway of D_s → PP: Cabibbo-favored, Singly-Cabibbo-Suppressed, and Doubly-Cabibbo-Suppressed, with the branch ratio calculated for each statistic mode. For example, the total events of $D^+ \to K^+K^-\pi+$ decay pathway are collected and screened as 89868 ± 369 events, with the branch ratio of 5.50 ± 0.17 [PDG][22].

10.8. There are data detected by other particle colliders of LHeC, which is published in China for comparison: under the collision energy level at $\sqrt{S}$ = 1.30 TeV with luminosity L = 10^{33} $cm^{-2}s^{-1}$, there are events collected by LHeC instrument:

$2.48^{+3.45}_{-1.55}$ ×10^4 B_c^{**} (^{1}P$_1$), $1.14^{+1.49}_{-0.82}$ ×10^4 B_c^{**} (^{3}P$_0$), $2.38^{+3.39}_{-1.74}$ ×10^4 B_c^{**} (^{3}P$_1$), and $5.59^{+7.84}_{-3.93}$×10^4 B_c^{**}(^{3}P$_2$). It is reported by He (2017) that the generation of P-wave B_c^{**} accounts for approximately 20% of background state recorded in LHeC and FCC-ep, and the exited state of B_c^{**} events are massively founded in LHeC and FCC-ep, which contributes to the mass spectrum of (c $\bar{b}$) bound states and validate the relevant conceptional models [21].

10.9. In comparison, the CMD-3 detector at the VEPP-2000 collider collected events under the parameters of central mass energy at 1.2~2.0 GeV with integrated luminosity of 3 × 10^4 nb $^{-1}$ in 2011 and 2012. The decaying process of $e^+e^- \rightarrow \eta\pi^+\pi^- \rightarrow \gamma\gamma\pi^+\pi^-$, $e^+e^- \rightarrow \eta\pi^+\pi^- \rightarrow \pi^0\pi^+\pi^-\pi^+\pi^-$ and $e^+e^- \rightarrow \omega\pi^+\pi^- \rightarrow \pi^0\pi^+\pi^-\pi^+\pi^-$ have been studied by Popov et al.,(2016). The Born cross section of decay pathway $e^+e^- \rightarrow \eta\pi^+\pi^-$ has been calculated, which shows consistence with other experiments results, and the branch ratio of $\tau^- \rightarrow \eta\pi^-\pi^0\nu\tau$ decay pathway has been also calculated as (0.147 ± 0.003(*stat.*) ± 0.006(*syst.*)) % on the basis of this Born cross section correspondingly. Other decay pathways of $e^+e^- \rightarrow \eta\pi^+\pi^-$ and $e^+e^- \rightarrow \omega\pi^+\pi^-$ to the final states $\eta \rightarrow \pi^+\pi^-\pi^0$ and $\omega \rightarrow \pi^+\pi^-\pi^0$ respectively have been studied with the preliminary results of Born cross sections as well but without further extrapolation[23].

10.10. The decay process of $e^+e^- \rightarrow K^+K^-\eta$ based on the events collected by CMD-3 detector at the integrated luminosity of 22 pb $^{-1}$ in 2011-2012 is studied by Invanov et al., (2016)[24]. It is confirmed that the intermediate resonance of φ(1020) is determined by the statistical measurement. For the decay pathway of $e^+e^- \rightarrow$ φ(1020) η, the cross section is derived from 30 of various energy levels ranging from 1.59 to 2.0 GeV. Further more, by using the model of vector meson dominance, the φ(1680) meson resonance has been estimated accordingly to the measured cross section [24]. Hence there are two methods used in this study to interpret the resonance parameters, direct measurement and modeling.

10.11.Two decay processes of $e^+e^- \rightarrow K_S^0 K_L^0$ and $e^+e^- \rightarrow K^+K^-$ have been studied by Kozyrev et al.,(2016) according to the events at 25 different energy levels ranging from 1004 to 1060 MeV, which is collected by the CMD-3 detector at the integrated luminosity of 5.5 pb $^{-1}$. The cross section of two decay pathways have been calculated on the basis of the events selected above, which is further integrated into the modeling of vector meson dominance, resulting in the estimation of φ(1020) meson parameters [25].

11. The Original Viewpoints

There are original viewpoints presented in my previous articles[18][19]:

1. After the atomic half-life, both the electrons moving in the unstable layer and the paired protons are separated from the internal spin trajectory of the atom and emitted to the outside of the atom due to the reduction of momentum in three-dimensional space, showing radioactivity. However, the positively charged protons emitted at this time are not separated from their paired electrons, but still paired due to the adhesion of dark matter in the fourth dimension. The specific motion characteristics in this scenario are below: the positively charged proton and its paired electron move like a spring as longitudinal wave motion along the fourth dimension axis; Due to the high-speed motion of protons in three-dimensional space, forming the cutting motion against the magnetic line on the fourth dimensional axis, protons continue to carry positive charges; However, in this pairing scenario, the polarity of the electrons points to the fourth dimensional axis, so the negative charge characteristics of the electrons appear in its fourth dimensional space and pair with the positively charged protons in three-dimensional space; The positively charged protons and its paired electrons moves like a spring as longitudinal wave motion on the fourth dimension axis, consequently producing a pulse wave. This pulse wave is the origin of α rays, β rays and γ rays in radioactive elements. Correspondingly, these rays has also become the strong evidence to prove the motion of paired charge particles, which can be simulated in the laboratory.

2. The design of the particle collider, in fact, the charged particle beams formed in the accelerator are similar to the positively charged particles emitted after the half-life of the atom. It is not the really atomic splitting in this scenario, but two paired positively and negatively charged particles on the fourth dimension axis move like spring as the longitudinal wave motion, in which one charged particle displays the amount of electric charges in three-dimensional space, and the other paired particle shows opposite charges in the fourth dimensional space. The pairs of positively and negatively charged particles make a spring longitudinal wave motion on the fourth dimension axis, resulting in pulsed electromagnetic waves. During the process of accelerating charged particle beam by accelerator in particle collider, the pulse electromagnetic wave detected is due to this reason. However, in this case, the paired particles of positive and negative charges as a whole still display the characteristics of neutral atoms, but the symmetry center of the spatial distribution of electric charges switches from three dimension spaces to the fourth dimension axis in this scenario.

3. Consequently, when two beams of charged particle collide in the particle collider, under the condition that the law of electromagnetic induction can be ignored, the kinetic mechanics of a beam of charged micro-particles only conforms to the principle of fluid mechanics (such as pressure calculations), and is not applicable on the mechanical energy law of solid collision (such as conservation of momentum).When the pressures produced by the beams of charged particles is enough, it is able to collide the nucleus of atoms, achieving the karyorrhexis of nucleus atoms. There are two reasons: the neutral magnetic field in atoms shields the approaching charged micro-particles; the dark matter underlay in the fourth dimension space of the atoms

materials being collided also affects the motion of a beam of charged micro-particles. Once a charged micro-particles stream approaches the aggregation of dark matter, dark matter produces a non-linear resistance buffer force. These two forces lead the charged micro-particles pass along the sides of atoms materials, so that only the principle of fluid mechanics is applicable. Both dark matter and anti-matter have been further discussed in my other articles [27][28].

4. From the viewpoint of force analysis on micro-particles, the momentum theorem is applicable between two objects' collision only if the two objects are endowed with the forces of the same nature. In this physical case, the charged micro-particles beams are derived by Coulomb force, whereas the atoms substances is given the mechanical force (it is unreasonable to conduct force analysis separately on the nucleus or electron within the neutral atom in this physical simulation case). Additionally, the dark matter produces non-linear buffer mutual forces among micro-objects including atoms or molecules, which leads the physical simulation of momentum theorem and conservation theorem of mechanical energy to be not applicable again. Consequently, the momentum theorem and conservation theorem of mechanical energy is applicable on the macro-physical solid objects only as approximate calculations, but is not applicable on the micro-physical simulations of particles motion.

5. The basic unit of elementary micro-particle partition and classification should be based on the basic unit of Coulomb force, which can be divided into three categories only: proton, electron and neutron. These elementary micro-particles randomly fluctuate along the fourth dimension axis, so the mass of micro-particles in the three dimensions space isn't constant. The mass M of elementary particles in three-dimensional space is a compound trigonometric function of time variable T and natural constant e (≈ 2.718281828459045). The smaller micro-particles (such as Quark) partitioned by the large particle collider technology are the proportional/partial mass of the elementary micro-particles occurring in the three-dimensional space at a certain time. Therefore, the physical parameters such as mass and charge in the experimental results should be defined as a variable that comforts to the probability distribution law in Statistics (different from the constant or irregular variables). Consequently, this kind of research method and technology should focus on the exploration of the movement law of elementary micro-particles on the four-dimensional axis, which is given more application significance, such as the foundation research of new materials synthesis. After the synchrotron phase, the charged particles collide in a vacuum ring tube under constant magnetic field intensity, so the tangent velocity of the charged particles that collide is relatively uniform velocity. Because charged particles in the particle collider experiment collide with each other in a relatively uniform velocity motion mode, if the particle mass is fixed, the particle mass and energy after collision segmentation should be relatively fixed, and should not be subdivided into such a large number of particles with different masses, especially when the collision experiment is applied to non radioactive elements.

6. In my essay: Materials and Thermodynamics, there are two major reasons to analyze the energy loss at quantum level: firstly, the aging of dark matter in materials leads to the energy lose, which is the most common reason in materials; secondly, energy lose is due to the decay of radioactive materials. However, this is usually less applicable on the stable materials without apparent radioactive characteristics. Further more, the relationship between the events detected by the particle collider and the particle mass/energy should be linked with the aging characters for the design of new materials synthesizing.

7. By comparison and contrast between the case studies in Table 1 below and the example of radium-226 reported in section 8, it is found that the branching ratio is reduced to such tiny probability when the particle is partitioned to finer scales compared with the decay pathway from radium-226 to radon-222 illustrated in section 8, for example, in case study 10.2, one of the branch ratio is 2.29×10^{-6}, which is much smaller than the branch ratio of 94.6% for decay pathway radium-226 → α particle→ radon-222. Further more, the events detected by the particle collider are screened and selective in all the case studies summarized in Table 1. This means that the probability of finer particle partitioning is the very tiny probability events compared with the total events detected by particle collision experiment, which is less reliable and less repeatable in Situ. Consequently, the discovery of particles partitioned into finer scales is definitely NOT the study focus in my future research. For the design of new materials synthesizing, the events detected by the particle collider should NOT be screened or selected, as to reveal the whole characters of materials, and the radioactive materials are not the main selection of particle collider study correspondingly. The relationship between the events detected by the particle collider and the particle mass/energy should be correlated with the aging characters of materials as the indicators evaluating materials application in engineering, which is similar to but not identical to the decay characters of radioactive materials.

8.The decay pathway calculation is NOT applicable on the materials without radioactive characters. The relationship between the events detected by the particle collider and the particle mass/energy mainly reflects the mass fluctuation of elementary particles along the fourth axis, which occurs in the three-dimension spaces in this situation and consequently measurable by particle colliders.

9.Mass and Energy Conversion: in section 5, it is argued that when a pair of positive and negative particles collides, they can annihilate and become quantum photons carrying energy, which means that the particle mass can be transformed into energy; On the contrary, when two high-energy particles collide, they may produce a pair of new positive and negative particles, which means that energy can also be transformed into the mass of particles. In my opinion, when a pair of positive and negative particles collides, they become neutron whose mass is reduced in the three dimension space due to less cutting motion along the fourth dimension axis by neutron compared with charged particles; On the contrary, when two high-energy particles collide, they may produce a pair of new positive and negative particles. This may occur when a neutron is partitioned into a pair of new positive and negative particles. Consequently, the conversion between mass and energy is understandable when the fourth dimension spaces is taken into consideration.

In the mass-energy conversion process releasing nuclear energy, the reduction in mass is divided into two types: one is the nuclear fission type, which is mainly caused by the decay and partition of radioactive elements; the other is the nuclear fusion process, in which the element particles are aggregated into more stable nucleus, and the total mass of element particles is reduced in the three-dimension space by the adhering force of dark matter binding these element particles into more stable and tighter nucleus. Both types of mass reduction releases nuclear energy.

10. Anti-particles: with regards to the reasons why there are both positive and negative types of β Decay: this article proposes that the type of β Decay process is mainly determined by the rotation orientations of free electrons around the rotation center point of an atom in the three dimensional spaces. In the electron clouds, if the free electron with rotation motion of clockwise orientation is emitted from the unstable atom, which is defined as the negative pole relatively to the nuclear of an atom, the nucleus would tend to be positive β decay process; if the free electron with rotation motion of anticlockwise orientation is emitted from the unstable atom, which is defined the positive pole relatively to the nuclear of an atom, the nucleus would tend to be negative β decay process. Consequently, the electrons can be both positive and negative poles relatively to the nucleus of an atom, rather than single pole to the nucleus [26].

11. With regards to gravitational wave generating mechanism:the generation of gravitational waves is the space-time bending phenomenon detected under the condition that the mass density and weight of celestial bodies increases significantly. This paper further proposes that the elementary particle motion model in the celestial body of this scenario is similar to that of the ray: the spring-type longitudinal wave motion is performed on the fourth dimension axis, and the pulse wave is generated. However, due to the high mass density of the celestial body that generates the gravitational wave and the aging effect of dark matter, the gravitational wave is low-frequency and long wave length, compared with the ray. It is deduced that in most cases, the higher the frequencies of gravitational wave, the younger the star form; the stronger intensity of gravitational wave, the heavier mass of the star system (or the stronger gravity per unit mass) to compress the charged elementary particles. When binary star merger happens, the elementary particles between binary stars absorb radiation energy firstly, turning into excited state with higher energy level and more free form (although this excited free form has not reached the ionization state). Then the elementary particles of excited state with more free form are further synthesized into degenerate matter by the gravity contraction. In this degenerate matter synthesis

process, the incident particles and atomic nuclei combine to form into metastable composite nucleus, which subsequently decays into the final stable particles in a period, further releasing radiation energy. This metastable composite nucleus as the combination of incident particles and nuclei is called the resonant state, and the final stable particles would be the final state of degenerate matter compressed by gravity [26].

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Table 1. Summarized Main Findings of Particle Collision Experiments Published in China.

Events	Decay Pathway	Branching Ratio	Exited State of Particle	Resonance State	Scattering Cross Section
4.48×10^{8} Ψ(3638)[13]	$\Psi\ (3638) \rightarrow \Lambda\,\overline{\Lambda}\,\omega$	(3.42 ± 0.34(*stat.*) ± 0.31(*syst.*)) × 10^{-5}	Λ* Mass: 2.001 ± 0.007 GeV; Width: 0.036 ± 0.014 GeV		
1.31×10^{9}[13]	$J/\Psi \rightarrow \Lambda\,\overline{\Lambda}\,\eta$	(19.93 ± 0.38(*stat.*) ± 0.14(*syst.*)) × 10^{-5}			
	$J/\Psi \rightarrow \Phi(2170)\eta \rightarrow \Lambda\,\overline{\Lambda}\,\eta$	2.29×10^{-6}			
	$J/\Psi \rightarrow X(2239)\eta \rightarrow \Lambda\,\overline{\Lambda}\,\eta$	3.31×10^{-6}			
φ(3770)[14]	$D^{+}\rightarrow\eta\pi0\pi+$	(2.23 ± 0.15(*stat.*) ± 0.13(*syst.*))× 10^{-3}			
	$D^{+}\rightarrow\eta\eta\pi+$	(2.96 ± 0.24(*stat.*) ± 0.13(*syst.*))× 10^{-3}			
	$D^{0} \rightarrow \eta\pi\text{-}\pi+$	(1.18 ± 0.07(*stat.*) ± 0.04(*syst.*))× 10^{-3}			
Υ (2175)[15]	$e + e^{-} \rightarrow \Phi\ \eta'$			Energy: 2.180 GeV; Mass: (2182.4 ± 5.1(*stat.*) ± 1.6(*syst.*)) MeV / C^{2} ; Width: (142.2 ± 16.6(*stat.*) ± 0.0(*syst.*)) MeV	
	$e + e^{-} \rightarrow K + k\text{-}\Phi$				
447.9×10^{6} ψ(2S)[16]	$\psi(2S)\rightarrow\pi^{0}hc$				
	hc → 3 (π+π-)	upper limit < 2.89×10^{-3}			
		X(1840)		X(1840)	

10×10^{9} events of J/ψ[16]	J/ψ→γ^{3}(π+π-)	$(1.76 \pm 0.07(stat.) \pm 0.59(syst.)) \times 10^{-5}$		Mass:$1823.6 \pm 2.5(stat.) \pm 0.5(syst.)$; Width:$94.0 \pm 8.9(stat.) \pm 25.7(syst.)$;	
		X (1880) $(0.94 \pm 0.03(stat.) \pm 0.25(syst.)) \times 10^{-5}$		X (1880) Mass:$1880.6 \pm 1.6(stat.) \pm 2.5(syst.)$; Width:$39.8 \pm 4.6(stat.) \pm 7.5(syst.)$;	
4.5×10^{8} events of Ψ(3686)[17]	$\Psi(3686) \to \overline{\Sigma}^{0} \Lambda + c.c.$	$(1.60 \pm 0.31(stat.) \pm 0.13(syst.) \pm 0.58(syst.+inter.)) \times 10^{-6}$			
	$\chi_{c0} \to \Lambda\overline{\Lambda}$	$(3.64 \pm 0.10(stat.) \pm 0.10(syst.) \pm 0.07)\times 10^{-4}$			
	$\chi_{c1} \to \Lambda\overline{\Lambda}$	$(1.31 \pm 0.06(stat.) \pm 0.06(syst.) \pm 0.03) \times 10^{-4}$			
	$\chi_{c2} \to \Lambda\overline{\Lambda}$	$(1.91 \pm 0.08(stat.) \pm 0.17 (syst.)\pm 0.04)\times10^{-4}$			
1.00×10^{5} events of Signal MC[20]	$e^{+}e^{-} \to \omega\eta$				BORN cross section
$2.48^{+3.45}_{-1.55}$ ×			B_c^{**}		

10^4 B_c^{**} ($^1P_1$), $1.14^{+1.49}_{-0.82}\times$ 10^4 B_c^{**} ($^3P_0$), $2.38^{+3.39}_{-1.74}\times$ 10^4 B_c^{**} ($^3P_1$), $5.59^{+7.84}_{-3.93}\times$ 10^4 B_c^{**} ($^3P_2$)[21]					
89868 ± 369 Ds [22]	$D^+ \to K^+K^-\pi+$	5.50 ± 0.17 [PDG]			
Events at integrated luminosity of 3×10^4 nb $^{-1}$ [23]	$e^+e^- \to \eta\pi^+\pi^- \to \gamma\gamma\pi^+\pi^-$; $e^+e^- \to \eta\pi^+\pi^- \to \pi^0\pi^+\pi^-\pi^+\pi^-$; $e^+e^- \to \omega\pi^+\pi^- \to \pi^0\pi^+\pi^-\pi^+\pi^-$	(0.147 ± 0.003(*stat.*) ± 0.006(*syst.*)) %			BORN cross section Fig9; Fig12;Fig13
Events at the integrated	$e^+e^- \to K^+K^-\eta$			φ(1020) meson by measurement method	BORN cross section
luminosity of 22 pb $^{-1}$[24]	$e^+e^- \to$ φ(1020) η			φ(1680) meson by modeling method	

Events at the integrated luminosity of 5.5 pb $^{-1}$[25]	$e^+e^- \rightarrow K_S^0 K_L^0$			φ(1020) meson by modeling method	BORN cross section
	$e^+e^- \rightarrow K^+K^-$				BORN cross section