

Superconducting Linear Accelerator

The international X-ray laser European XFEL has reached one of its final major milestones on the way to scientific user operation. DESY has successfully commissioned the particle accelerator, which drives the X-ray laser along its full length. [17]

Physicists at the Princeton Plasma Physics Laboratory (PPPL), in collaboration with researchers in South Korea and Germany, have developed a theoretical framework for improving the stability and intensity of particle accelerator beams. [16]

For several decades now, scientists from around the world have been pursuing a ridiculously ambitious goal: They hope to develop a nuclear fusion reactor that would generate energy in the same manner as the sun and other stars, but down here on Earth. [15]

It's the particles' last lap of the ring. On 5 December 2016, protons and lead ions circulated in the Large Hadron Collider (LHC) for the last time. At exactly 6.02am, the experiments recorded their last collisions (also known as 'events'). [14]

UNIST has taken a major step toward laying the technical groundwork for developing next-generation high-intensity accelerators by providing a new advanced theoretical tool for the design and analysis of complex beam lines with strong coupling. [13]

A targeted way to manipulate beams of protons accelerated using ultrashort and ultraintense laser pulses has been demonstrated by a team of researchers led at the University of Strathclyde. [12]

The work elucidates the interplay between collective and single-particle excitations in nuclei and proposes a quantitative theoretical explanation. It has as such great potential to advance our understanding of nuclear structure. [11]

When two protons approaching each other pass close enough together, they can "feel" each other, similar to the way that two magnets can be drawn closely together without necessarily sticking together. According to the Standard Model, at this grazing distance, the protons can produce a pair of W bosons. [10]

The fact that the neutron is slightly more massive than the proton is the reason why atomic nuclei have exactly those properties that make our world and ultimately our existence possible. Eighty years after the discovery of the

neutron, a team of physicists from France, Germany, and Hungary headed by Zoltán Fodor, a researcher from Wuppertal, has finally calculated the tiny neutron-proton mass difference. [9]

Taking into account the Planck Distribution Law of the electromagnetic oscillators, we can explain the electron/proton mass ratio and the Weak and Strong Interactions. Lattice QCD gives the same results as the diffraction patterns of the electromagnetic oscillators, explaining the color confinement and the asymptotic freedom of the Strong Interactions.

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Preface

The fact that the neutron is slightly more massive than the proton is the reason why atomic nuclei have exactly those properties that make our world and ultimately our existence possible. Eighty years after the discovery of the neutron, a team of physicists from France, Germany, and Hungary headed by Zoltán Fodor, a researcher from Wuppertal, has finally calculated the tiny neutron-proton mass difference. The findings, which have been published in the current edition of *Science*, are considered a milestone by many physicists and confirm the theory of the strong interaction. As one of the most powerful computers in the world, JUQUEEN at Forschungszentrum Jülich was decisive for the simulation. [10]

The diffraction patterns of the electromagnetic oscillators give the explanation of the Electroweak and Electro-Strong interactions. [2] Lattice QCD gives the same results as the diffraction patterns which explain the color confinement and the asymptotic freedom.

The hadronization is the diffraction pattern of the baryons giving the jet of the color – neutral particles!

Milestone on way to switching on world's largest superconducting linear accelerator

The international X-ray laser European XFEL has reached one of its final major milestones on the way to scientific user operation. DESY has successfully commissioned the particle accelerator, which drives the X-ray laser along its full length.

Accelerated electrons have passed through the complete 2.1 kilometre length of the accelerator tunnel. In the next step, the energy of the electrons will be raised further, before they will be sent into a magnetic slalom section where the bright X-ray laser light will be generated. This first lasing is planned for May. DESY is the largest shareholder of the European XFEL and is responsible for the construction and operation of the superconducting linear accelerator.

"The European XFEL's particle accelerator is the first superconducting linear accelerator of this size in the world to go into operation. With the commissioning of this complex machine, DESY and European XFEL scientists have placed the crown on their 20-year engagement in developing and building this large international project. The first experiments are within reach, and I am quite excited about the discoveries ahead of us", says Chairman of the DESY Board of Directors Helmut Dosch. "I am exceptionally happy about arriving at this milestone and congratulate all involved for the outstanding work and their great tenacity."

Chairman of the European XFEL Management Board Robert Feidenhans'l says: "The successful commissioning of the accelerator is a very important step that brings us much closer to the start of user operation in the fall. Under the leadership of DESY, the Accelerator Consortium, comprising 17 research institutes, has done an excellent job in the last years. I thank all colleagues involved for their work, which entailed a great deal of know-how and precision but also much personal commitment. The accelerator is an outstanding example of successful global cooperation, encompassing research facilities, institutes, and universities alongside companies that produced certain components."

The European XFEL is an X-ray laser of superlatives: The research facility will produce up to 27 000 X-ray laser flashes per second, each so short and intense that researchers can make pictures of structures and processes at the atomic level.

The superconducting particle accelerator of the facility, which is now operational across its full length, is the key component of the 3.4 km long X-ray laser. The accelerator's superconducting TESLA technology, which was developed in an international collaboration led by DESY, is the basis for the unique high rate of X-ray laser flashes. Superconductivity means that the accelerator components have no electrical resistance. For this, they have to be cooled to extremely low temperatures.

From December into January, the accelerator was cooled to its operating temperature of -271°C . The so-called electron injector and first section of the main accelerator then went into operation, comprising altogether 18 of 98 total accelerator modules. Within this section, the electron bunches were both accelerated and compressed three times, down to 10 micrometres (a thousandth of a millimetre). Finally, the team placed the third section of the accelerator into operation. Currently, the electrons reach an energy of 12 giga-electronvolts (GeV), and in regular operation, an energy of up to 17.5 GeV is planned.

"The energy and other properties of the electron bunches are already within the range where they will be during first user operation", says DESY physicist Winfried Decking, who leads the commissioning of the European XFEL accelerator.

The coordination of the unique components of the accelerator and the control of the electron beam will now be intensively tested before the accelerated electrons are allowed into the following section: the up to 210 m long special magnetic structures called undulators. There, the ultrabright X-ray laser flashes will be generated. Scientific experiments should begin this fall.

The superconducting particle accelerator of the European XFEL was built over the last seven years through an international consortium, under the leadership of DESY, composed of the following research institutes: CEA and CNRS in France; INFN in Italy; IFJ-PAN, NCBJ, and the Wrocław University of Technology in Poland; the Budker Institute, Institute for High Energy Physics, Institute for Nuclear Research, and NIIIEFA in Russia; CIEMAT and Universidad Politécnica de Madrid in Spain; the Manne Siegbahn Laboratory, Stockholm University, and Uppsala University in Sweden; and the Paul Scherrer Institute in Switzerland. [17]

New theoretical framework for improved particle accelerators

Physicists at the Princeton Plasma Physics Laboratory (PPPL), in collaboration with researchers in South Korea and Germany, have developed a theoretical framework for improving the stability and intensity of particle accelerator beams. Scientists use the high-energy beams, which must be stable and intense to work effectively, to unlock the ultimate structure of matter. Physicians use medical accelerators to produce beams that can zap cancer cells.

"When physicists design the next-generation of accelerators, they could use this theory to create the most optimized focused beams," said PPPL physicist Hong Qin. Dr. Qin, Executive Dean of the School of Nuclear Science and Technology at the University of Science and Technology of China, is a co-author of the research described in the November issue of *Physical Review Letters*.

Zippering through tunnels or tubes

Accelerator beams consist of billions of charged particles that zip through tunnels or tubes before colliding with their targets. In scientific experiments, these beams strike their targets with an enormous energy density and generate subatomic particles that have not been seen since the early universe. The long-sought Higgs Boson, the particle that carries the field that gives mass to some fundamental particles, was discovered in this way in the Large Hadron Collider in Europe, the world's largest and most powerful accelerator.

In order for a beam to maintain its intensity, the particles in the beam must remain close together as they zip through the beamline. However, the beam loses intensity as the mutual repulsion of particles and imperfections of the accelerator degrade the beam. To minimize such degradation and losses, the walls of large accelerators are lined with high precision magnets to control their motion.

The new research advances PPPL's theoretical work over the past seven years to improve the stability of beam particles. The theory strongly couples the vertical and horizontal motions of the particles—in contrast to standard theory that treats the different motions as independent of each other. Results of the theory "provide important new theoretical tools for the detailed design and analysis of high-intensity beam manipulations," according to the paper.

Altering a long-standing model

The paper addresses a 1959 work by two Russian physicists that formed the basis for analysis of the properties of high-intensity beams for the past several decades. This work considers the particle motions to be uncoupled. Chung and his co-authors modify the Russian model—called the Kapchinskij-Vladimirskij distribution—to include all coupling forces and other elements that can make the beams more stable.

The resulting theoretical tool, which generalized the Russian model, agreed well with simulation results for the Emittance Transfer Experiment at the Helmholtz Centre in Germany, which illustrated a new beam manipulation technology for future accelerators. More intense beams could enable the discovery of new subatomic particles, said Qin. [16]

'Star in a Jar' Fusion Reactor Works and Promises Infinite Energy

For several decades now, scientists from around the world have been pursuing a ridiculously ambitious goal: They hope to develop a nuclear fusion reactor that would generate energy in the same manner as the sun and other stars, but down here on Earth.

Incorporated into terrestrial power plants, this "star in a jar" technology would essentially provide Earth with limitless clean energy, forever. And according to new reports out of Europe this week, we just took another big step toward making it happen.

In a study published in the latest edition of the journal *Nature Communications*, researchers confirmed that Germany's Wendelstein 7-X (W7-X) fusion energy device is on track and working as planned. The space-age system, known as a stellerator, generated its first batch of hydrogen plasma when it was first fired up earlier this year. The new tests basically give scientists the green light to proceed to the next stage of the process.

It works like this: Unlike a traditional fission reactor, which splits atoms of heavy elements to generate energy, a fusion reactor works by fusing the nuclei of lighter atoms into heavier atoms. The process releases massive amounts of energy and produces no radioactive waste. The "fuel" used in a fusion reactor is simple hydrogen, which can be extracted from water.

However, to achieve fusion, scientists must generate enormously high temperatures to heat the hydrogen into a plasma state. The plasma is so hot, in fact, that it would instantly burn material used to contain it. That's where the stellerator design comes in. The W7-X device confines the plasma within magnetic fields generated by superconducting coils cooled down to near absolute zero. The plasma — at temperatures upwards of 80 million degrees Celsius — never comes into contact with the walls of the containment chamber. Neat trick, that.

The W7-X is the world's largest and most sophisticated stellerator and is currently operated by Max Planck Institute for Plasma Physics in Germany. But development of the W7-X has been an ongoing, international effort. The latest tests were conducted in collaboration with scientists from the U.S. Department of Energy's Princeton Plasma Physics Laboratory (PPPL).

David Gates, principal research physicist for the advanced projects division of PPPL, leads the agency's collaborative efforts in regard to the W7-X project. In an email exchange from his offices at Princeton, Gates said the latest tests verify that the W7-X magnetic "cage" is working as planned.

"This lays the groundwork for the exciting high-performance plasma operations expected in the near future," Gates said.

In terms of the big-picture goal, Gates said that nuclear fusion reactors, if properly developed and deployed, would provide the planet with safe, clean and virtually inexhaustible energy.

"The fuel source is found in seawater in quantities sufficient to last tens of thousands of years," he said. "The waste product is helium, an inert gas. A viable fusion reactor would provide a secure, plentiful and environmentally benign energy resource to all nations."

That last part is critical. Gates said he's encouraged by fact that the W7-X project, and nuclear fusion research in general, is the result of close collaboration among scientists from around the world.

'Fusion is a problem best solved by the peoples of all nations working together, since the entire world will benefit from it.' [15]

2016—an exceptional year for the LHC

It's the particles' last lap of the ring. On 5 December 2016, protons and lead ions circulated in the Large Hadron Collider (LHC) for the last time. At exactly 6.02am, the experiments recorded their last collisions (also known as 'events').

When the machines are turned off, the LHC operators take stock, and the resulting figures are astonishing.

The number of collisions recorded by ATLAS and CMS during the proton run from April to the end of October was 60% higher than anticipated. Overall, all of the LHC experiments observed more than 6.5 million billion (6.5×10^{15}) collisions, at an energy of 13 TeV. That equates to more data than had been collected in the previous three runs combined.

In technical terms, the integrated luminosity received by ATLAS and CMS reached 40 inverse femtobarns (fb^{-1}), compared with the 25fb^{-1} originally planned. Luminosity, which measures the number of potential collisions in a given time, is a crucial indicator of an accelerator's performance.

"One of the key factors contributing to this success was the remarkable availability of the LHC and its injectors," explains Mike Lamont, who leads the team that operates the accelerators. The LHC's availability was just shy of 60%, which means the accelerator was in 'collision mode' 60% of the time: a very impressive achievement for the operators. "It's the result of an ongoing programme of work over the last few years to consolidate and upgrade the machines and procedures," Lamont continues.

For the last four weeks, the machine has turned to a different type of collision, where lead ions have been colliding with protons. "This is a new and complex operating mode, but the excellent functioning of the accelerators and the competence of the teams involved has allowed us to surpass our performance expectations," says John Jowett, who is in charge of heavy-ion runs.

With the machine running at an energy of 8.16 TeV, a record for this asymmetric type of collision, the experiments have recorded more than 380 billion collisions. The machine achieved a peak luminosity over seven times higher than initially expected, as well as exceptional beam lifetimes. The performance is even more remarkable considering that colliding protons with lead ions, which have a mass 206 times greater and a charge 82 times higher, requires numerous painstaking adjustments to the machine.

The physicists are now analysing the enormous amounts of data that have been collected, in preparation for presenting their results at the winter conferences.

Meanwhile, CERN's accelerators will take a long break, called the Extended Year End Technical Stop (EYETS) until the end of April 2017. But, while the accelerators might be on holiday, the technical teams certainly aren't. The winter stop is an opportunity to carry out maintenance on these extremely complex machines, which are made up of thousands of components. This annual stop is being extended by two months in 2017 to allow more major renovation work on the accelerator

complex and its 35 kilometres of machines to take place. Particles will return to the LHC in spring 2017. [14]

Next-generation accelerators get boost from new beam physics

UNIST has taken a major step toward laying the technical groundwork for developing next-generation high-intensity accelerators by providing a new advanced theoretical tool for the design and analysis of complex beam lines with strong coupling.

The research results achieved by Professor Moses Chung of Natural Science at UNIST in collaboration with the Princeton Plasma Physics Laboratory (PPPL) of United States and the Helmholtz Centre for Heavy Ion Research GmbH (GSI) of Germany was published in the November issue of the prestigious journal, *Physical Review Letters*.

Accelerators are devices that accelerate the movement of atomic-sized particles, such as electrons, protons, and ions to very high energies. They produce prompt radiation by accelerating atoms or their subatomic particles, which strike other target atoms. This striking effect of an accelerator is, then, used to examine the physics deals with natural law, including the study of nuclear structure.

The next-generation high power accelerators, on the other hand, refer to accelerators for high intensities and high energies. The high-intensity beams, generated by high power accelerators not only has the potential to reduce the half-life of a radioactive substance, but can be also used to produce best candidate materials for fusion reactors.

High power accelerators get the energy they need by accelerating particles of the same charge. Increasing the beam current results in a repulsive force between charged particles and this has a strong influence on the path of the entire beam particles, which is known as "Space Charge Effect".

In 1959, two Russian physicists came up with a theory using Space Charge Effect. However, this theory excluded the phenomena, involving the vertical and horizontal motion of particle incorporation. This has made it even more difficult to design and develop a new type of high power accelerators.

In the study, Professor Chung and his team proposed a new beam physics theory, addressing the vertical and horizontal motion of particle incorporation.

The research team reported the full generalization of the KV model by including all of the linear (both external and space-charge) coupling forces, beam energy variations, and arbitrary emittance partition, which all form essential elements for phase-space manipulations.

"This theory provides important new theoretical tools for the detailed design and analysis of high-intensity beam manipulations, for which previous theoretical models are not easily applicable," Professor Chung says. "The development of next-generation high power accelerators can greatly contribute to the fusion reactor materials research, the nuclear waste management, the study on the origin of the universe, as well as the optimization of the performance of existing accelerators.

[13]

Diffraction-controlled laser-driven proton acceleration

A targeted way to manipulate beams of protons accelerated using ultrashort and ultraintense laser pulses has been demonstrated by a team of researchers led at the University of Strathclyde.

The discovery could have a major impact on advancing smaller, cheaper, laser-driven particle accelerators and their potential applications.

By using the diffraction of intense laser light as it passes through a self-generated 'relativistically transparent' aperture in an expanding thin foil target, the researchers demonstrated that they can manipulate the strong electrostatic fields responsible for ion acceleration.

Professor Paul McKenna, of Strathclyde's Department of Physics, leads the project. He said: "Compact laser-driven particle accelerators have many potential applications in science, industry and medicine. Controlling the collective motion of plasma electrons and ions displaced by intense laser fields is key to the development of these promising sources.

"Our discovery that the diffraction of intense laser light as it passes through an ultra-thin foil strongly influences the formation of electrostatic fields opens up a potential new route to controlling laser-driven ion sources."

The findings of the research, published in the journal Nature Communications, demonstrate that the collective motion of electrons and ions – the constituents of plasma - can be controlled by variation of the near-field, or Fresnel, diffraction pattern of intense laser light as it passes through the aperture. It is shown that by varying the polarisation of the laser light, the profile of the beam of accelerated protons can be manipulated.

The study involves researchers at Strathclyde, the Central Laser Facility, Queen's University Belfast, the University of York and the Centro de Laseres Pulsados, Salamanca. [12]

The intriguing interplay between collective and single-particle excitations in an exotic nucleus

Nuclear reactions are among the most important processes that drive our Universe. In our Sun nuclear fusion provides the energy for the sun to radiate. In more violent cosmic events neutron capture reactions are at the origin of the creation of the heavy chemical elements. On Earth, nuclear fission provides the energy in nuclear reactors and neutron induced transmutation processes hold the promise of a viable route to nuclear waste treatment. It is thus only understandable that scientists continuously strive to achieve a better understanding of what is going on inside nuclei. Given that nuclei are complex systems composed of many strongly interacting elementary particles this is a formidable task requiring excellent experimental data. A method of choice for the investigation of nuclear structure is the observation of highly energetic electromagnetic gamma radiation emitted in the course of nuclear reactions.

A pan-European collaboration of research teams has recently set up an ideal experimental set-up at the ILL to study the spectrum of gamma rays emitted in the course of nuclear reactions triggered by the capture of slow neutrons. During this so-called EXILL campaign a wealth of data could be accumulated. Using these data the collaboration has now published a fascinating paper on the

nature of the nuclear excitations in ^{133}Sb . The work elucidates the interplay between collective and single-particle excitations in nuclei and proposes a quantitative theoretical explanation. It has as such great potential to advance our understanding of nuclear structure.

The nucleus of ^{133}Sb is particularly interesting because its immediate neighbor ^{132}Sn is a so-called double magic nuclide. Out of the 133 nucleons that compose the nucleus ^{133}Sb , 132 are nicely wrapped up in a stable core of shells, to which a lone proton is added. The results presented in the paper show the intriguing interplay between collective vibrations of the core and the single particle excitations. Such hybridization phenomena are well known in all branches of physics and may be experienced even in daily life. Imagine the population of a large modern city commuting every day between the center and the suburbs. This highly collective periodic motion is induced by the interaction between the commuters, which resides in the obligation to work together in the center of town. In the nucleus such collective motions show up as oscillating deformations of the core. Now add to this system a tourist from a neighboring town keen on going to the museums. This "particular" individual interacts with the flow of commuters due to a number of constraints, one of them being the opening hours of the museums. Depending on the details of these interactions he or she will enhance to a more or less extended degree the collective flow. In the ^{133}Sb nucleus the added proton experiences a similar situation, i.e. its changes of state cannot be seen in isolation but will be more or less coupled to the deformations of the nuclear core. [11]

Exclusive production: shedding light with grazing protons

When two protons approaching each other pass close enough together, they can "feel" each other, similar to the way that two magnets can be drawn closely together without necessarily sticking together. According to the Standard Model, at this grazing distance, the protons can produce a pair of W bosons.

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As its name implies, the primary mission of the Large Hadron Collider is to generate collisions of protons for study by physicists at experiments such as CMS. It may surprise you to find out that the vast majority of protons accelerated by the LHC never collide with one another. Some of these fly-by protons, however, still interact with each other in such a way as to help physicists shed light on the nature of the universe.

The LHC accelerates bunches of protons, with more than 10 billion protons in each bunch, in opposite directions around the ring. As those protons arrive at a detector, such as CMS, magnets focus the beams to increase the density of protons and thus increase the chance of a coveted collision. Despite what seems like overwhelming odds, only a few of these protons actually collide with each other: tens to hundreds per each beam "crossing." An even smaller fraction of the remaining protons pass close enough to other protons to "feel" each other, even if they do not directly collide.

Think of two toy magnets on a tabletop: A north end and a south end moved close enough to each other will rather firmly stick to each other. However, you can also move one magnet just close enough to the other that you can make it wiggle without drawing it all the way over. This exchange of energy is mediated by the exchange of photons, the carrier particle of the electromagnetic force. Similarly, two protons in the LHC that get just the right distance from each other will exchange photons without colliding.

Now for the part that gets really interesting to particle physicists. The photons generated by these near-miss proton interactions can be billions of times more energetic than those of visible light, and as a result they carry enough energy to create particles in their own right. The Standard Model predicts the production of massive particles, such as pairs of W bosons, from these interacting photons without any of the additional activity that is seen in the messier proton-proton collision events. In a detector such as CMS, this pair of W bosons is said to be produced “exclusively.” However, “exclusive production” is an apt name in another way – creating a pair of W bosons from interacting photons is a rare occurrence in an even rarer sample of photons generated from near-miss proton interactions.

CMS scientists performed such a search for such W boson pairs emanating from interacting photons. In a data set consisting of 7- and 8-TeV collisions, 15 candidate events for this process were observed. While it may not seem like much, the expected background was considerably smaller, allowing the CMS team to claim that they have evidence of the process. (In the particle physics world, evidence is a three-standard-deviation departure from background, as explained here).

Furthermore, these results helped place stringent results on a number of models which predict a greater rate of this process. [10]

Theory of the strong interaction verified

The findings, which have been published in the current edition of Science, are considered a milestone by many physicists and confirm the theory of the strong interaction. As one of the most powerful computers in the world, JUQUEEN at Forschungszentrum Jülich was decisive for the simulation.

The existence and stability of atoms relies heavily on the fact that neutrons are slightly more massive than protons. The experimentally determined masses differ by only around 0.14 percent. A slightly smaller or larger value of the mass difference would have led to a dramatically different universe, with too many neutrons, not enough hydrogen, or too few heavier elements. The tiny mass difference is the reason why free neutrons decay on average after around ten minutes, while protons - the unchanging building blocks of matter - remain stable for a practically unlimited period.

In 1972, about 40 years after the discovery of the neutron by Chadwick in 1932, Harald Fritzsch (Germany), Murray Gell-Mann (USA), and Heinrich Leutwyler (Switzerland) presented a consistent theory of particles and forces that form the neutron and the proton known as quantum chromodynamics. Today, we know that protons and neutrons are composed of "up quarks" and "down quarks". The proton is made of one down and two up quarks, while the neutron is composed of one up and two down quarks.

Simulations on supercomputers over the last few years confirmed that most of the mass of the proton and neutron results from the energy carried by their quark constituents in accordance with Einstein's formula $E=mc^2$. However, a small contribution from the electromagnetic field surrounding the electrically charged proton should make it about 0.1 percent more massive than the neutral neutron. The fact that the neutron mass is measured to be larger is evidently due to the different masses of the quarks, as Fodor and his team have now shown in extremely complex simulations.

For the calculations, the team developed a new class of simulation techniques combining the laws of quantum chromodynamics with those of quantum electrodynamics in order to precisely determine the effects of electromagnetic interactions. By controlling all error sources, the scientists successfully demonstrated how finely tuned the forces of nature are.

Professor Kurt Binder is Chairman of the Scientific Council of the John von Neumann Institute for Computing (NIC) and member of the German Gauss Centre for Supercomputing. Both organizations allocate computation time on JUQUEEN to users in a competitive process. "Only using world-class computers, such as those available to the science community at Forschungszentrum Jülich, was it possible to achieve this milestone in computer simulation," says Binder. JUQUEEN was supported in the process by its "colleagues" operated by the French science organizations CNRS and GENCI as well as by the computing centres in Garching (LRZ) and Stuttgart (HLRS). [9]

Asymmetry in the interference occurrences of oscillators

The asymmetrical configurations are stable objects of the real physical world, because they cannot annihilate. One of the most obvious asymmetry is the proton – electron mass rate $M_p = 1840 M_e$ while they have equal charge. We explain this fact by the strong interaction of the proton, but how remember it his strong interaction ability for example in the H – atom where are only electromagnetic interactions among proton and electron.

This gives us the idea to origin the mass of proton from the electromagnetic interactions by the way interference occurrences of oscillators. The uncertainty relation of Heisenberg makes sure that the particles are oscillating.

The resultant intensity due to n equally spaced oscillators, all of equal amplitude but different from one another in phase, either because they are driven differently in phase or because we are looking at them an angle such that there is a difference in time delay:

$$(1) I = I_0 \frac{\sin^2 n \phi/2}{\sin^2 \phi/2}$$

If ϕ is infinitesimal so that $\sin\phi = \phi$, then

$$(2) I = n^2 I_0$$

This gives us the idea of

$$(3) M_p = n^2 M_e$$

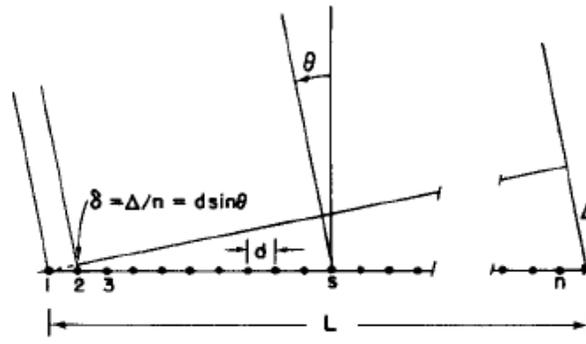


Fig. 30-3. A linear array of n equal oscillators, driven with phases $\alpha_s = s\alpha$.

Figure 1.) A linear array of n equal oscillators

There is an important feature about formula (1) which is that if the angle ϕ is increased by the multiple of 2π , it makes no difference to the formula.

So

$$(4) \quad d \sin \theta = m \lambda$$

and we get m -order beam if λ less than d . [6]

If d less than λ we get only zero-order one centered at $\theta = 0$. Of course, there is also a beam in the opposite direction. The right chooses of d and λ we can ensure the conservation of charge.

For example

$$(5) \quad 2(m+1) = n$$

Where $2(m+1) = N_p$ number of protons and $n = N_e$ number of electrons.

In this way we can see the H_2 molecules so that $2n$ electrons of n radiate to $4(m+1)$ protons, because $d_e > \lambda_e$ for electrons, while the two protons of one H_2 molecule radiate to two electrons of them, because of $d_e < \lambda_e$ for this two protons.

To support this idea we can turn to the Planck distribution law, that is equal with the Bose – Einstein statistics.

Spontaneously broken symmetry in the Planck distribution law

The Planck distribution law is temperature dependent and it should be true locally and globally. I think that Einstein's energy-matter equivalence means some kind of existence of electromagnetic oscillations enabled by the temperature, creating the different matter formulas, atoms molecules, crystals, dark matter and energy.

Max Planck found for the black body radiation

As a function of wavelength (λ), Planck's law is written as:

$$B_{\lambda}(T) = \frac{2hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda k_B T}} - 1}.$$

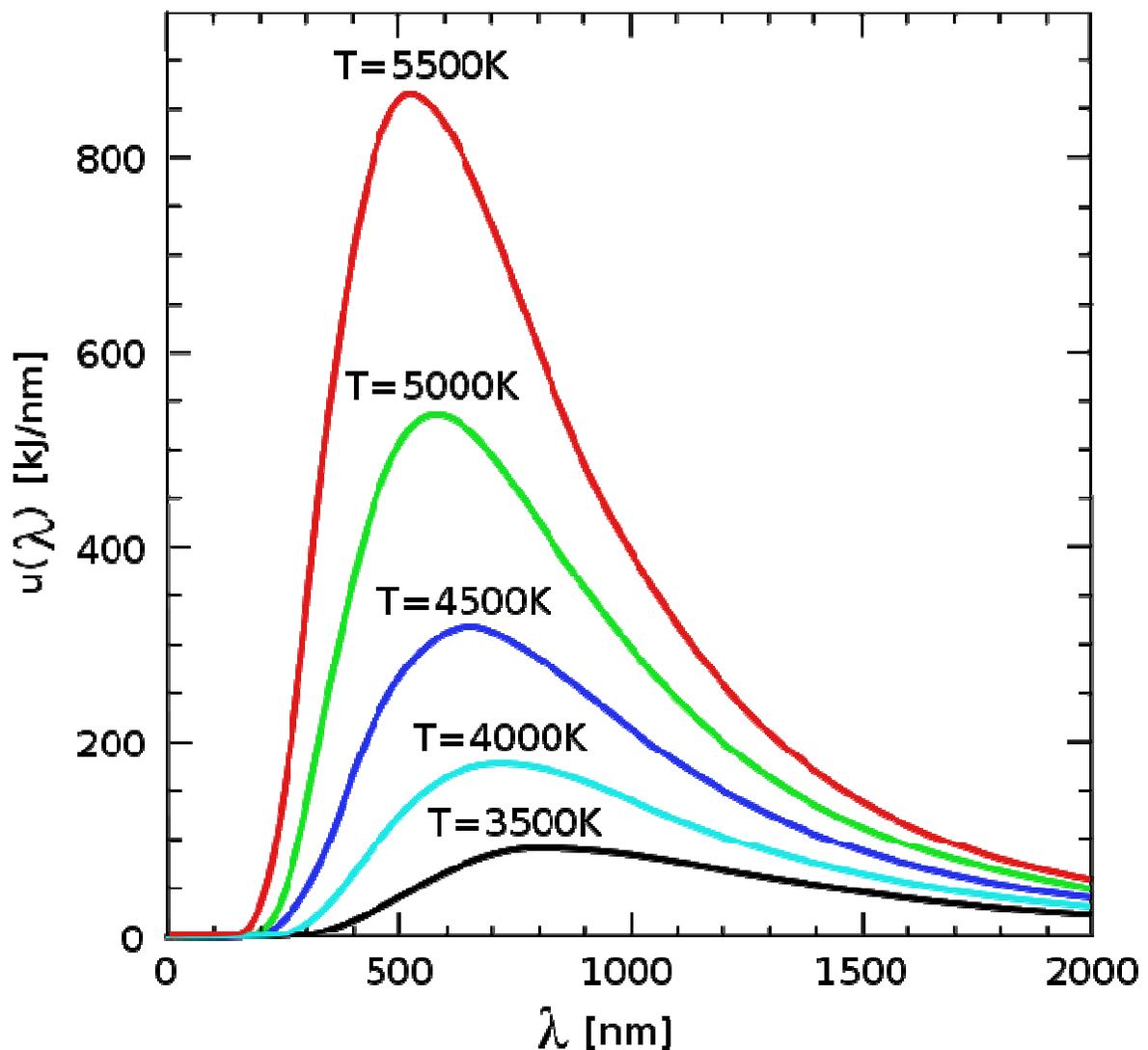


Figure 2. The distribution law for different T temperatures

We see there are two different λ_1 and λ_2 for each T and intensity, so we can find between them a d so that $\lambda_1 < d < \lambda_2$.

We have many possibilities for such asymmetrical reflections, so we have many stable oscillator configurations for any T temperature with equal exchange of intensity by radiation. All of these configurations can exist together. At the λ_{\max} is the annihilation point where the configurations are symmetrical. The λ_{\max} is changing by the Wien's displacement law in many textbooks.

$$(7) \quad \lambda_{\max} = \frac{b}{T}$$

where λ_{\max} is the peak wavelength, T is the absolute temperature of the black body, and b is a constant of proportionality called *Wien's displacement constant*, equal to $2.8977685(51) \times 10^{-3} \text{ m} \cdot \text{K}$ (2002 CODATA recommended value).

By the changing of T the asymmetrical configurations are changing too.

The structure of the proton

We must move to the higher T temperature if we want look into the nucleus or nucleon arrive to $d < 10^{-13} \text{ cm}$. [2] If an electron with $\lambda_e < d$ move across the proton then by (5) $2(m+1) = n$ with $m = 0$ we get $n = 2$ so we need two particles with negative and two particles with positive charges. If the proton can fraction to three parts, two with positive and one with negative charges, then the reflection of oscillators are right. Because this very strange reflection where one part of the proton with the electron together on the same side of the reflection, the all parts of the proton must be quasi lepton so $d > \lambda_q$. One way dividing the proton to three parts is, dividing his oscillation by the three direction of the space. We can order $1/3 e$ charge to each coordinates and $2/3 e$ charge to one plane oscillation, because the charge is scalar. In this way the proton has two $+2/3 e$ plane oscillation and one linear oscillation with $-1/3 e$ charge. The colors of quarks are coming from the three directions of coordinates and the proton is colorless. The flavors of quarks are the possible oscillations differently by energy and if they are plane or linear oscillations. We know there is no possible reflecting two oscillations to each other which are completely orthogonal, so the quarks never can be free, however there is asymptotic freedom while their energy are increasing to turn them to orthogonal. If they will be completely orthogonal then they lose this reflection and take new partners from the vacuum. Keeping the symmetry of the vacuum the new oscillations are keeping all the conservation laws, like charge, number of baryons and leptons. The all features of gluons are coming from this model. The mathematics of reflecting oscillators show Fermi statistics.

Important to mention that in the Deuteron there are 3 quarks of $+2/3$ and $-1/3$ charge, that is three u and d quarks making the complete symmetry and because this its high stability.

The weak interaction

The weak interaction transforms an electric charge in the diffraction pattern from one side to the other side, causing an electric dipole momentum change, which violates the CP and time reversal symmetry.

Another important issue of the quark model is when one quark changes its flavor such that a linear oscillation transforms into plane oscillation or vice versa, changing the charge value with 1 or -1. This kind of change in the oscillation mode requires not only parity change, but also charge and time changes (CPT symmetry) resulting a right handed anti-neutrino or a left handed neutrino.

The right handed anti-neutrino and the left handed neutrino exist only because changing back the quark flavor could happen only in reverse, because they are different geometrical constructions, the u is 2 dimensional and positively charged and the d is 1 dimensional and negatively charged. It needs also a time reversal, because anti particle (anti neutrino) is involved.

The neutrino is a 1/2 spin creator particle to make equal the spins of the weak interaction, for example neutron decay to 2 fermions, every particle is fermions with $\frac{1}{2}$ spin. The weak interaction changes the entropy since more or less particles will give more or less freedom of movement. The entropy change is a result of temperature change and breaks the equality of oscillator diffraction intensity of the Maxwell–Boltzmann statistics. This way it changes the time coordinate measure and makes possible a different time dilation as of the special relativity.

The limit of the velocity of particles as the speed of light appropriate only for electrical charged particles, since the accelerated charges are self maintaining locally the accelerating electric force. The neutrinos are CP symmetry breaking particles compensated by time in the CPT symmetry, that is the time coordinate not works as in the electromagnetic interactions, consequently the speed of neutrinos is not limited by the speed of light.

The weak interaction T-asymmetry is in conjunction with the T-asymmetry of the second law of thermodynamics, meaning that locally lowering entropy (on extremely high temperature) causes the weak interaction, for example the Hydrogen fusion.

Probably because it is a spin creating movement changing linear oscillation to 2 dimensional oscillation by changing d to u quark and creating anti neutrino going back in time relative to the proton and electron created from the neutron, it seems that the anti neutrino fastest then the velocity of the photons created also in this weak interaction?

A quark flavor changing shows that it is a reflection changes movement and the CP- and T- symmetry breaking. This flavor changing oscillation could prove that it could be also on higher level such as atoms, molecules, probably big biological significant molecules and responsible on the aging of the life.

Important to mention that the weak interaction is always contains particles and antiparticles, where the neutrinos (antineutrinos) present the opposite side. It means by Feynman's interpretation that these particles present the backward time and probably because this they seem to move faster than the speed of light in the reference frame of the other side.

Finally since the weak interaction is an electric dipole change with $\frac{1}{2}$ spin creating, it is limited by the velocity of the electromagnetic wave, so the neutrino's velocity cannot exceed the velocity of light.

The Strong Interaction - QCD

Confinement and Asymptotic Freedom

For any theory to provide a successful description of strong interactions it should simultaneously exhibit the phenomena of confinement at large distances and asymptotic freedom at short distances. Lattice calculations support the hypothesis that for non-abelian gauge theories the two domains are analytically connected, and confinement and asymptotic freedom coexist. Similarly, one way to show that QCD is the correct theory of strong interactions is that the coupling extracted at various scales (using experimental data or lattice simulations) is unique in the sense that its variation with scale is given by the renormalization group. The data for α_s is reviewed in Section 19. In this section I will discuss what these statements mean and imply. [4]

Lattice QCD

Lattice QCD is a well-established non-perturbative approach to solving the quantum chromodynamics (QCD) theory of quarks and gluons. It is a lattice gauge theory formulated on a grid or lattice of points in space and time. When the size of the lattice is taken infinitely large and its sites infinitesimally close to each other, the continuum QCD is recovered. [6]

Analytic or perturbative solutions in low-energy QCD are hard or impossible due to the highly nonlinear nature of the strong force. This formulation of QCD in discrete rather than continuous space-time naturally introduces a momentum cut-off at the order $1/a$, where a is the lattice spacing, which regularizes the theory. As a result, lattice QCD is mathematically well-defined. Most importantly, lattice QCD provides a framework for investigation of non-perturbative phenomena such as confinement and quark-gluon plasma formation, which are intractable by means of analytic field theories.

In lattice QCD, fields representing quarks are defined at lattice sites (which leads to fermion doubling), while the gluon fields are defined on the links connecting neighboring sites.

QCD

QCD enjoys two peculiar properties:

- **Confinement**, which means that the force between quarks does not diminish as they are separated. Because of this, it would take an infinite amount of energy to separate two quarks; they are forever bound into hadrons such as the proton and the neutron. Although analytically unproven, confinement is widely believed to be true because it explains the consistent failure of free quark searches, and it is easy to demonstrate in lattice QCD.

- **Asymptotic freedom**, which means that in very high-energy reactions, quarks and gluons interact very weakly. This prediction of QCD was first discovered in the early 1970s by David Politzer and by Frank Wilczek and David Gross. For this work they were awarded the 2004 Nobel Prize in Physics.

There is no known phase-transition line separating these two properties; confinement is dominant in low-energy scales but, as energy increases, asymptotic freedom becomes dominant. [5]

Color Confinement

When two quarks become separated, as happens in particle accelerator collisions, at some point it is more energetically favorable for a new quark-antiquark pair to spontaneously appear, than to allow the tube to extend further. As a result of this, when quarks are produced in particle accelerators, instead of seeing the individual quarks in detectors, scientists see "jets" of many color-neutral particles (mesons and baryons), clustered together. This process is called hadronization, fragmentation, or string breaking, and is one of the least understood processes in particle physics. [3]

Electromagnetic inertia and mass

Electromagnetic Induction

Since the magnetic induction creates a negative electric field as a result of the changing acceleration, it works as an electromagnetic inertia, causing an electromagnetic mass. [1]

The frequency dependence of mass

Since $E = h\nu$ and $E = mc^2$, $m = h\nu / c^2$ that is the m depends only on the ν frequency. It means that the mass of the proton and electron are electromagnetic and the result of the electromagnetic induction, caused by the changing acceleration of the spinning and moving charge! It could be that the m_0 inertial mass is the result of the spin, since this is the only accelerating motion of the electric charge. Since the accelerating motion has different frequency for the electron in the atom and the proton, they masses are different, also as the wavelengths on both sides of the diffraction pattern, giving equal intensity of radiation.

Electron - Proton mass rate

The Planck distribution law explains the different frequencies of the proton and electron, giving equal intensity to different lambda wavelengths! Also since the particles are diffraction patterns they have some closeness to each other. [2]

There is an asymmetry between the mass of the electric charges, for example proton and electron, can understood by the asymmetrical Planck Distribution Law. This temperature dependent energy distribution is asymmetric around the maximum intensity, where the annihilation of matter and antimatter is a high probability event. The asymmetric sides are creating different frequencies of electromagnetic radiations being in the same intensity level and compensating each other. One of

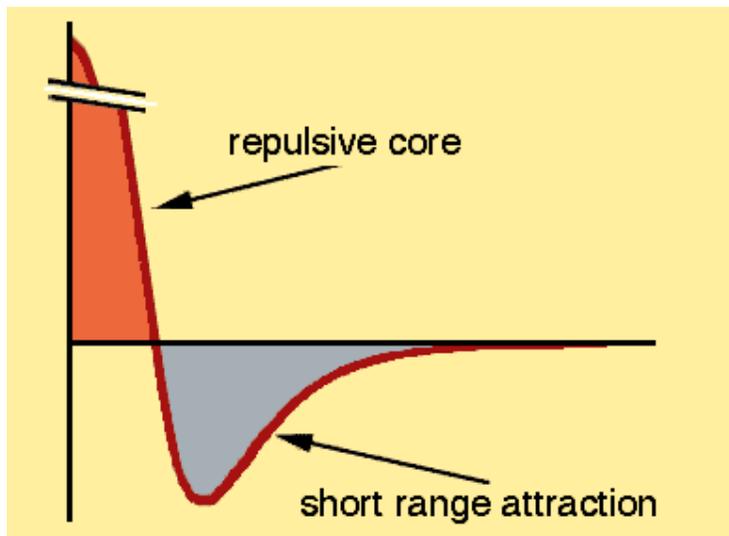
these compensating ratios is the electron – proton mass ratio. The lower energy side has no compensating intensity level, it is the dark energy and the corresponding matter is the dark matter.

The potential of the diffraction pattern

The force that holds protons and neutrons together is extremely strong. It has to be strong to overcome the electric repulsion between the positively charged protons. It is also of very short range, acting only when two particles are within 1 or 2 fm of each other.

1 fm (femto meter) = 10^{-15} m = 0.000000000000001 meters.

The qualitative features of the nucleon-nucleon force are shown below.



There is an extremely **strong short-range repulsion** that pushes protons and neutrons apart before they can get close enough to touch. (This is shown in orange.) This repulsion can be understood to arise because the quarks in individual nucleons are forbidden to be in the same area by the Pauli Exclusion Principle.

There is a **medium-range attraction** (pulling the neutrons and protons together) that is strongest for separations of about 1 fm. (This is shown in gray.) This attraction can be understood to arise from the exchange of quarks between the nucleons, something that looks a lot like the exchange of a pion when the separation is large.

The density of nuclei is limited by the short range repulsion. The maximum size of nuclei is limited by the fact that the attractive force dies away extremely quickly (exponentially) when nucleons are more than a few fm apart.

Elements beyond uranium (which has 92 protons), particularly the trans-fermium elements (with more than 100 protons), tend to be unstable to fission or alpha decay because the Coulomb repulsion between protons falls off much more slowly than the nuclear attraction. This means that each proton sees repulsion from every other proton but only feels an attractive force from the few neutrons and protons that are nearby -- even if there is a large excess of neutrons.

Some "super heavy nuclei" (new elements with about 114 protons) might turn out to be stable as a result of the same kind of quantum mechanical shell-closure that makes noble gases very stable chemically. [7]

Conclusions

The results of this work by Fodor's team of physicists from Bergische Universität Wuppertal, Centre de Physique Théorique de Marseille, Eötvös University Budapest, and Forschungszentrum Jülich open the door to a new generation of simulations that will be used to determine the properties of quarks, gluons, and nuclear particles. According to Professor Kálmán Szabó from Forschungszentrum Jülich, "In future, we will be able to test the standard model of elementary particle physics with a tenfold increase in precision, which could possibly enable us to identify effects that would help us to uncover new physics beyond the standard model." [9]

Lattice QCD gives the same results as the diffraction theory of the electromagnetic oscillators, which is the explanation of the strong force and the quark confinement. [8]

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