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Chapter 1 : MULTI-FACETED SUCCESS: Conversation with Sir Chris Llewellyn Smith - SCGP

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But Rees argues that for many long-term policy issues, this specialist knowledge informs the debate without providing a solution. Deciding whether to build wind farms or nuclear power plants to keep the lights on is not a technical decision, but an economic and social one. Technical expertise means that scientist can play a privileged role in these debates. But Rees argues that this privilege must not be abused; scientists must show humility about the bounds of their expertise. In many areas, they are informed citizens or, as Rees puts it, scientific citizens: As an aside, his section on generalities includes some very quotable home truths from a senior scientist. I have picked out a few from the full text: You will notice the Royal Society science policy centre namechecks â€" apologies for the inadvertent self-promotion. What challenges does the future hold for the relationship between science and policy? I speak with diffidence â€" there are some people here this evening with far deeper experience than I have. But my years as President of the Royal Society, where we had a policy unit excellently led by James Wilsdon, gave me a privileged breadth of perspective, as well as international links that offered a comparison with other countries. As compared to the US, for instance, the interface with government is closer, the respect for evidence is stronger and the rapport between scientists and legislators is certainly better. And, unlike any other European Country except Switzerland, the UK has a chief scientific adviser to the government. Generally the chief scientists come from outside Whitehall for years â€" they may keep a foothold in a university or research lab for one or two days a week. They have the handicap of needing to learn the ways of the civil service in order to operate, but external appointees are thought to be best. There have been very capable and energetic incumbents in these roles â€" it would be invidious to mention names. In particular, the issues are often more engineering than academic. For instance, the commitment to a huge number of offshore wind-turbines by â€" constructing one per two days â€" is widely regarded as unrealistic. It might have been better to have had more engineering scrutiny at the department Board when this policy was promulgated. It was really during World War II that scientists first became really engaged in government. Experts should be prepared to challenge decision-makers, and help them navigate the uncertainties. This was recognised in the US by President Obama. When really big and long-term policies are in contention â€" whether about nuclear weapons, nuclear power, drug classification, or health risks â€" political decisions are seldom purely scientific: And in domains beyond their special expertise, scientists speak just as citizens, with no enhanced authority. Sometimes, governments need urgent advice on an issue where one can separate out the science. In that instance, the knowledge was basically there: And this year, John Beddington was asked what advice should be given to Brits in Japan after the Fukushima episode â€" was there a radiation risk even in Tokyo? Here again, the situation on the ground was unclear but the underlying science was basically known. But it proved wrong. The pendulum then swung the other way. We fret unduly about carcinogens in food and low level radiation. Should we build nuclear power stations â€" or wind farms â€" if we want to keep the lights on? Should we use more insecticides, or plant GM crops? How do we respond to long term environmental and climatic risks? Moreover the stakes are getting higher â€" and the issues more global. The threat of global nuclear annihilation has been in abeyance since the Cold War ended. For instance, global society depends on elaborate networks â€" electricity grids, air traffic control, international finance, just-in-time delivery and so forth. Unless these are highly resilient, their manifest benefits could be outweighed by catastrophic albeit rare breakdowns cascading through the system. And the threat is terror as well as error; concern about cyber-attack, by criminals or by hostile nations, is rising sharply. Synthetic biology, likewise, offers huge potential for medicine and agriculture â€" but it could facilitate bioterror. This is a much-studied scenario of course. But the message is that the impediments are political and economic, not technical. GM was part of the prescription but only part â€" improved irrigation, low till farming, better refrigeration to cut waste, and so forth are equally necessary. But population is an issue. The rise is projected to continue at least until Whether the rising trend continues beyond will depend on what people now in their teens and 20s decide about the number and spacing of their children. Hundreds of millions of women are denied such a choice. It should be important and timely. And also the huge regional variations. We should welcome an expanded and more networked world, where China and other countries follow the trajectory of Singapore or South Korea And now to another imponderable that might impact especially severely on the developing world: On this topic the Royal Society has been thoroughly engaged â€" with the science, the politics and the public perception. Straightforward chemistry tells us that the CO2 build-up will induce a long-term warming trend, superimposed on all the other complicated effects that make climate fluctuate. Nonetheless, even the existing uncertain science convinces me that the threat of seriously disruptive climate change is high enough to justify its priority on the political agenda. The science is intricate. It poses a unique political challenge for two reasons. First, the effect is non-localised: CO2 emissions from this country have no more effect here than they do in Australia, and vice versa. Second, there are long time-lags â€" it takes decades for the oceans to adjust to a new equilibrium, and centuries for ice-sheets to melt completely. And there are other questions. How much should we sacrifice now to ensure that the world is no worse when our grandchildren grow old? How much subsidy should be transferred from the rich world, whose fossil fuel emissions have mostly caused the problem, to the developing nations? Should we gamble that our successors may devise a technical fix that will render nugatory any actions we take now? As I already noted about science advice in general. Risk assessment should be separate from risk management. Googling any disease reveals a bewildering range of purported remedies. Next, some comments on energy supply and security. This is a key issue in its own right, quite apart from its impact on the climate. The world spends more than 5 trillion dollars a year on energy and its infrastructure. But currently far too little is invested in developing techniques for economising on energy, storing it and generating it by low-carbon methods. The main US investments are in small start-up companies, especially in solar energy. And in the UK energy R and D has barely crept back up to its level in before it plummeted after the privatisations that occurred at that time. Indeed it would be hard to think of anything more likely to enthuse young people towards careers in engineering that a firmly-proclaimed priority to develop clean energy for the developing and the developed world. What are the options? This island nation has the geography â€" capes round its coast with fast-flowing tidal currents â€" and also expertise in marine technology spun off from North Sea oil and gas projects. But in the long run GM techniques may lead to novel developments: Another need is for improved energy storage. In the US, Steve Chu has given priority to improving batteries â€" for electric cars, and to complement unsteady power sources such as sun and wind. What is the role of nuclear power? But the nuclear non-proliferation regime is fragile. The industry has been relatively dormant for the last 20 years, and current designs date back to the s. And of course, nuclear fusion still beckons as an inexhaustible source of energy. An alternative concept, whereby tiny deuterium pellets are zapped by converging beams from immense lasers, is being touted by the Livermore Laboratory in the US, but this facility seems primarily a defence project to provide lab-scale substitutes for H-bomb tests, where the promise of controlled fusion power is a political fig leaf â€" I got angry e-mails from Livermore when I said this last year. Many of us still hope that our civilisation can segue towards a low-carbon future without trauma and disaster. But what is very important is to prioritise the development of those new energy sources â€" be they wind, tides or solar or nuclear. The political problems of such geoengineering may be overwhelming. Not all nations would want to turn down the thermostat equally, and there could be unintended side- effects. Moreover, the warming would return with a vengeance of the countermeasures were ever discontinued; and other consequences of rising CO2 especially the deleterious effects of ocean acidification would be unchecked. An alternative strategy which currently seems less practicable would involve direct extraction of carbon from the atmosphere. Very elaborate climatic modelling would be needed in order to calculate the regional impacts of such an intervention. Back now to some generalities. For politicians, the urgent trumps the important. And getting re-elected trumps almost everything. Anything that gets them into the press, or makes their postbag bulge, will get attention. Research is professionalised, and technical. Darwin was the last great scientist whose discoveries could be fully presented in accessible prose â€" indeed in fine literature. Science writers and journalists do an important job â€" and a difficult one. I know how hard it is to explain in clear language even something I understand well. But journalists have the far greater challenge of assimilating topics quite new to them, often to a tight deadline; some are required to speak at short notice, without hesitation, deviation or repetition, before a microphone or TV camera. And professional scientists are an important part of their audience.

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Chapter 2 : Nuclear Fusion : WNA - World Nuclear Association

*The JET Project and the Prospects for Controlled Nuclear Fusion (Royal Society Discussion Volumes) [R S Pease, R J Bickerton, B E Keen] on blog.quintoapp.com *FREE* shipping on qualifying offers. This volume presents reviews of the principles of the method and engineering realization of JET.*

From to Allied and Axis scientists threw their weight into the war knowing that their influence would have enormous consequences for mankind. A Scottish chemist has recently thought up an unusual application for Scotch whisky: One over the eighty: What does this level mean? How will the scientific analyses be carried out? But we are ill adapted for this new conquest; to us it is a hostile environment. Under water we are inefficient and inadequate compared with the giant fish and the sea mammals whose world it is. Horizon looks at how scientists are helping men enter this new world. How does a modern restorer set about preserving for a few more centuries a year-old masterpiece? In the next decade, jet airliners will carry up to five hundred passengers and fly faster than sound. Their airframes and engines will be tested to the most extreme safety limits. But what of the pilot who will fly these planes? Will we be able to test his ability in this critical job in a comparable fashion? Or of a Shakespeare composing a sonnet? Can experiments on rats or monkeys tell us anything about human behaviour in science and art? Arthur Koestler takes a critical look at some theories of human creativity and puts his own views. For five years he has worked with a reputable psychiatrist, and academic staff of Denver University, who believe the phenomenon is genuine; undoubtedly pictures are produced. For two days in the U. Is this a case for science to take seriously? Or is he a trickster? Do you own a toy? Did you ever own a toy? It traces his career from his early work on airships in the s, on air-raid shelter design during the war, to his present-day influence on young engineers in his department at Cambridge. Some American doctors argue that our research is held back by a lack of suitable animals. How necessary is vivisection? Could research still be done without the laboratory animal? Does our present system make It too easy for the casual drug experimenter to become a hard-core addict? Is there anything we can learn from the American situation? Horizon, with the guidance of a British psychiatrist, looks at some of the lessons which treatment centres in the U. Professor Colin Buchanan shows the overwhelming importance of this gap In town-planning and points to a future that could be liberated by the motor vehicle, or strangled by it. Just how much can we hope to add usefully to the human body? Could a limb or even a brain be transplanted? Can organs be stored so that the life of one man is not dependent on the death of another?. A personal view by an eminent social psychiatrist of the pleasures and problems of life in Britain in in comparison with a very different culture he knows intimately-Hindu village life in Northern India. He looks at some of our deeply rooted beliefs and how they affect our behaviour towards among other things, bereavement, sex, happiness and old-age; and at some of our growing social problems such as the rapidly increasing phenomenon of attempted suicide. The certainty and ingenuity of science is helping more and more to establish the outcome of a case. The scientifically trained detective at the scene of the crime, the pathologist in the mortuary, and the biochemist in the laboratory can each supply the piece of the jigsaw that solves the crime, and often a routine scientific test can establish guilt more decisively than half a dozen eye-witnesses.

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Chapter 3 : Nuclear Fusion Power â€“ CVD

Royal Society Discussion Meeting: the JET Project and the Prospect for Controlled Nuclear Fusion.

World Nuclear Association Updated November Fusion power offers the prospect of an almost inexhaustible source of energy for future generations, but it also presents so far insurmountable engineering challenges. The fundamental challenge is to achieve a rate of heat emitted by a fusion plasma that exceeds the rate of energy injected into the plasma. The main hope is centred on tokamak reactors and stellarators which confine a deuterium-tritium plasma magnetically. But the cost and complexity of the devices involved increased to the point where international co-operation was the only way forward. Fusion powers the Sun and stars as hydrogen atoms fuse together to form helium, and matter is converted into energy. Hydrogen, heated to very high temperatures changes from a gas to a plasma in which the negatively-charged electrons are separated from the positively-charged atomic nuclei ions. Normally, fusion is not possible because the strongly repulsive electrostatic forces between the positively charged nuclei prevent them from getting close enough together to collide and for fusion to occur. However, if the conditions are such that the nuclei can overcome the electrostatic forces to the extent that they can come within a very close range of each other, then the attractive nuclear force which binds protons and neutrons together in atomic nuclei between the nuclei will outweigh the repulsive electrostatic force, allowing the nuclei to fuse together. Such conditions can occur when the temperature increases, causing the ions to move faster and eventually reach speeds high enough to bring the ions close enough together. The nuclei can then fuse, causing a release of energy. Fusion technology In the Sun, massive gravitational forces create the right conditions for fusion, but on Earth they are much harder to achieve. Fusion fuel â€" different isotopes of hydrogen â€" must be heated to extreme temperatures of the order of 50 million degrees Celsius, and must be kept stable under intense pressure, hence dense enough and confined for long enough to allow the nuclei to fuse. Once ignition is achieved, there is net energy yield â€" about four times as much as with nuclear fission. According to the Massachusetts Institute of Technology MIT , the amount of power produced increases with the square of the pressure, so doubling the pressure leads to a fourfold increase in energy production. With current technology, the reaction most readily feasible is between the nuclei of the two heavy forms isotopes of hydrogen â€" deuterium D and tritium T. Each D-T fusion event releases Deuterium occurs naturally in seawater 30 grams per cubic metre , which makes it very abundant relative to other energy resources. Tritium occurs naturally only in trace quantities produced by cosmic rays and is radioactive, with a half-life of around 12 years. Usable quantities can be made in a conventional nuclear reactor, or in the present context, bred in a fusion system from lithium. In a fusion reactor, the concept is that neutrons generated from the D-T fusion reaction will be absorbed in a blanket containing lithium which surrounds the core. The lithium is then transformed into tritium which is used to fuel the reactor and helium. The kinetic energy of the neutrons is absorbed by the blanket, causing it to heat up. The heat energy is collected by the coolant water, helium or Li-Pb eutectic flowing through the blanket and, in a fusion power plant, this energy will be used to generate electricity by conventional methods. If insufficient tritium is produced, some supplementary source must be employed such as using a fission reactor to irradiate heavy water or lithium with neutrons, and extraneous tritium creates difficulties with handling, storage and transport. The difficulty has been to develop a device that can heat the D-T fuel to a high enough temperature and confine it long enough so that more energy is released through fusion reactions than is used to get the reaction going. While the D-T reaction is the main focus of attention, long-term hopes are for a D-D reaction, but this requires much higher temperatures. In any case, the challenge is to apply the heat to human needs, primarily generating electricity. The energy density of fusion reactions in gas is very much less than for fission reactions in solid fuel, and as noted the heat yield per reaction is 70 times less. Hence thermonuclear fusion will always have a much lower power density than nuclear fission, which means that any fusion reactor needs to be larger and therefore more costly, than a fission reactor of the same power output. In addition, nuclear fission reactors use solid fuel which is denser than a thermonuclear plasma, so the energy released is more concentrated. At present, two main experimental approaches are being studied: The first method uses strong magnetic fields to contain the hot plasma. The second involves compressing a small pellet containing fusion fuel to extremely high densities using strong lasers or particle beams. Magnetic confinement In magnetic confinement fusion MCF , hundreds of cubic metres of D-T plasma at a density of less than a milligram per cubic metre are confined by a magnetic field at a few atmospheres pressure and heated to fusion temperature. Magnetic fields are ideal for confining a plasma because the electrical charges on the separated ions and electrons mean that they follow the magnetic field lines. The aim is to prevent the particles from coming into contact with the reactor walls as this will dissipate their heat and slow them down. The most effective magnetic configuration is toroidal, shaped like a doughnut, in which the magnetic field is curved around to form a closed loop. For proper confinement, this toroidal field must have superimposed upon it a perpendicular field component a poloidal field. The result is a magnetic field with force lines following spiral helical paths that confine and control the plasma. There are several types of toroidal confinement system, the most important being tokamaks, stellarators and reversed field pinch RFP devices. In a tokamak, the toroidal field is created by a series of coils evenly spaced around the torus-shaped reactor, and the poloidal field is created by a system of horizontal coils outside the toroidal magnet structure. A strong electric current is induced in the plasma using a central solenoid, and this induced current also contributes to the poloidal field. In a stellarator, the helical lines of force are produced by a series of coils which may themselves be helical in shape. Unlike tokamaks, stellarators do not require a toroidal current to be induced in the plasma. RFP devices have the same toroidal and poloidal components as a tokamak, but the current flowing through the plasma is much stronger and the direction of the toroidal field within the plasma is reversed. In tokamaks and RFP devices, the current flowing through the plasma also serves to heat it to a temperature of about 10 million degrees Celsius. Beyond that, additional heating systems are needed to achieve the temperatures necessary for fusion. In stellarators, these heating systems have to supply all the energy needed. The tokamak toroidalnya kamera ee magnetnaya katushka â€" torus-shaped magnetic chamber was designed in by Soviet physicists Andrei Sakharov and Igor Tamm. Tokamaks operate within limited parameters outside which sudden losses of energy confinement disruptions can occur, causing major thermal and mechanical stresses to the structure and walls. Nevertheless, it is considered the most promising design, and research is continuing on various tokamaks around the world. Research is also being carried out on several types of stellarator. Lyman Spitzer devised and began work on the first fusion device â€" a stellarator â€" at the Princeton Plasma Physics Laboratory in Due to the difficulty in confining plasmas, stellarators fell out of favour until computer modelling techniques allowed accurate geometries to be calculated. Because stellarators have no toroidal plasma current, plasma stability is increased compared with tokamaks. Since the burning plasma can be more easily controlled and monitored, stellerators have an intrinsic potential for steady-state, continuous operation. The disadvantage is that, due to their more complex shape, stellarators are much more complex than tokamaks to design and build. RFP devices differ from tokamaks mainly in the spatial distribution of the toroidal magnetic field, which changes sign at the edge of the plasma. The RFX machine in Padua, Italy is used to study the physical problems arising from the spontaneous reorganisation of the magnetic field, which is an intrinsic feature of this configuration. Inertial confinement In inertial confinement fusion ICF , which is a newer line of research, laser or ion beams are focused very precisely onto the surface of a target, which is a pellet of D-T fuel, a few millimetres in diameter. This heats the outer layer of the material, which explodes outwards generating an inward-moving compression front or implosion that compresses and heats the inner layers of material. The core of the fuel may be compressed to one thousand times its liquid density, resulting in conditions where fusion can occur. The energy released then would heat the surrounding fuel, which may also undergo fusion leading to a chain reaction known as ignition as the reaction spreads outwards through the fuel. The time required for these reactions to occur is limited by the inertia of the fuel hence the name , but is less than a microsecond. So far, most inertial confinement work has involved lasers. Magnetized target fusion Magnetized target fusion MTF , also referred to as magneto-inertial fusion MIF , is a pulsed approach to fusion that combines the compressional heating of inertial confinement fusion with the magnetically reduced thermal transport and magnetically enhanced alpha heating of magnetic confinement fusion. A range of MTF systems are currently being experimented with, and commonly use a magnetic field to confine a plasma with compressional heating provided by laser, electromagnetic or mechanical liner implosion. As a result of this combined approach, shorter plasma confinement times are required than for magnetic confinement from ns to 1 ms, depending on the MIF approach , reducing the requirement to stabilize the plasma for long periods. Conversely, compression can be achieved over timescales longer than those typical for inertial confinement, making it possible to achieve compression through mechanical, magnetic, chemical, or relatively low-powered laser drivers. Due to the reduced demands on confinement time and compression velocities, MTF has been pursued as a lower-cost and simpler approach to investigating these challenges than conventional fusion projects. Hybrid fusion Fusion can also be combined with fission in what is referred to as hybrid nuclear fusion where the blanket surrounding the core is a subcritical fission reactor. The fusion reaction acts as a source of neutrons for the surrounding blanket, where these neutrons are captured, resulting in fission reactions taking place. These fission reactions would also produce more neutrons, thereby assisting further fission reactions in the blanket. The concept of hybrid fusion can be compared with an accelerator-driven system ADS , where an accelerator is the source of neutrons for the blanket assembly, rather than nuclear fusion reactions see page on Accelerator-driven Nuclear Energy. The blanket of a hybrid fusion system can therefore contain the same fuel as an ADS â€" for example, the abundant element thorium or the long-lived heavy isotopes present in used nuclear fuel from a conventional reactor could be used as fuel. A further advantage of a hybrid system is that the fusion part would not need to produce as many neutrons as a non-hybrid fusion reactor would in order to generate more power than is consumed â€" so a commercial-scale fusion reactor in a hybrid system does not need to be as large as a fusion-only reactor. Fusion research A long-standing quip about fusion points out that, since the s, commercial deployment of fusion power has always been about 40 years away. While there is some truth in this, many breakthroughs have been made, particularly in recent years, and there are a number of major projects under development that may bring research to the point where fusion power can be commercialised. Much research has also been carried out on stellarators. It is being used to study the best magnetic configuration for plasma confinement. In the USA, at Princeton Plasma Physics Laboratory, where the first stellarators were built in , construction on the NCSX stellerator was abandoned in due to cost overruns and lack of funding 2. There have also been significant developments in research into inertial confinement fusion. Both are designed to deliver, in a few billionths of a second, nearly two million joules of light energy to targets measuring a few millimeters in size. The four parties agreed in to collaborate further on engineering design activities for ITER. Canada and Kazakhstan are also involved through Euratom and Russia, respectively. The envisaged energy gain is unlikely to be enough for a power plant, but it should demonstrate feasibility. In , the USA rejoined the project and China also announced it would join. The deal involved major concessions to Japan, which had put forward Rokkasho as a preferred site. India became the seventh member of the ITER consortium at the end of The total cost of the MW ITER comprises about half for the ten-year construction and half for 20 years of operation. Site preparation works at Cadarache commenced in January First concrete for the buildings was poured in December Experiments were due to begin in , when hydrogen will be used to avoid activating the magnets, but this is now expected in The first D-T plasma is not expected until ITER is large because confinement time increases with the cube of machine size. The vacuum vessel will be 19 m across and 11 m high, and weigh more than tonnes. The goal of ITER is to operate with a plasma thermal output of MW for at least seconds continuously with less than 50 MW of plasma heating power input. No electricity will be generated at ITER. It is focused on the divertor structure to remove helium, testing the durability of tungsten materials used.

Chapter 4 : Fusion energy using tokamaks: can development be accelerated? | Royal Society

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Self-organizing plasma conducts electric and magnetic fields. Its motions can generate fields that can in turn contain it. This can reject an externally applied magnetic field, making it diamagnetic. The simplest is to heat a fluid. Most designs concentrate on the D-T reaction, which releases much of its energy in a neutron. Electrically neutral, the neutron escapes the confinement. In most such designs, it is ultimately captured in a thick "blanket" of lithium surrounding the reactor core. When struck by a high-energy neutron, the lithium can produce tritium, which is then fed back into the reactor. The energy of this reaction also heats the blanket, which is then actively cooled with a working fluid and then that fluid is used to drive conventional turbomachinery. It has also been proposed to use the neutrons to breed additional fission fuel in a blanket of nuclear waste , a concept known as a fission-fusion hybrid. In these systems, the power output is enhanced by the fission events, and power is extracted using systems like those in conventional fission reactors. In these cases, alternate power extraction systems based on the movement of these charges are possible. Direct energy conversion was developed at LLNL in the s as a method to maintain a voltage using the fusion reaction products. This has demonstrated energy capture efficiency of 48 percent. This method races hot plasma around in a magnetically confined, donut-shaped ring, with an internal current. As of April an estimated experimental tokamaks were either planned, decommissioned or currently operating 35 worldwide. Twisted rings of hot plasma. The stellarator attempts to create a natural twist plasma path, using external magnets, while tokamaks create those magnetic fields using an internal current. Stellarators were developed by Lyman Spitzer in and have four designs: Torsatron, Heliotron, Heliac and Helias. One example is Wendelstein 7-X , a German fusion device that produced its first plasma on December 10, These use a solid superconducting torus. This is magnetically levitated inside the reactor chamber. The superconductor forms an axisymmetric magnetic field that contains the plasma. Developed by Richard F. Post and teams at LLNL in the s. Variations included the Tandem Mirror , magnetic bottle and the biconic cusp. A number of magnetic mirrors are arranged end-to-end in a toroidal ring. Any fuel ions that leak out of one are confined in a neighboring mirror, permitting the plasma pressure to be raised arbitrarily high without loss. This device traps plasma in a self-organized quasi-stable structure; where the particle motion makes an internal magnetic field which then traps itself. A spheromak has both a toroidal and poloidal fields, while a Field Reversed Configuration only has no toroidal field. Here the plasma moves inside a ring. It has an internal magnetic field. Moving out from the center of this ring, the magnetic field reverses direction. Inertial confinement[edit] Direct drive: In this technique, lasers directly blast a pellet of fuel. The goal is to ignite a fusion chain reaction. Ignition was first suggested by John Nuckolls, in Good implosions require fuel pellets with close to a perfect shape in order to generate a symmetrical inward shock wave that produces the high-density plasma. This method uses two laser blasts. The first blast compresses the fusion fuel, while the second high energy pulse ignites it. In this technique, lasers blasts a structure around the pellet of fuel. This structure is known as a Hohlraum. As it disintegrates the pellet is bathed in a more uniform x-ray light, creating better compression. The largest system using this method is the National Ignition Facility. Magneto-inertial fusion or Magnetized Liner Inertial Fusion: This combines a laser pulse with a magnetic pinch. The pinch community refers to it as magnetized liner Inertial fusion while the ICF community refers to it as magneto-inertial fusion. Magnetic or electric pinches[edit] Main article: Pinch plasma physics Z-Pinch: This method sends a strong current in the z-direction through the plasma. The current generates a magnetic field that squeezes the plasma to fusion conditions. Pinches were the first method for man-made controlled fusion. In DPF the focus consists of two coaxial cylindrical electrodes made from copper or beryllium and housed in a vacuum chamber containing a low-pressure fusible gas. An electrical pulse is applied across the electrodes, heating the gas into a plasma. The current forms into a minuscule vortex along the axis of the machine, which then kinks into a cage of current with an associated magnetic field. The cage of current and magnetic-field-entrapped plasma is called a plasmoid. The acceleration of the electrons about the magnetic field lines heats the nuclei within the plasmoid to fusion temperatures. This method sends a current inside a plasma, in the theta direction. This method combines a theta and z-pinch for improved stabilization. Inertial Electrostatic Confinement Fusor: This method uses an electric field to heat ions to fusion conditions. The machine typically uses two spherical cages, a cathode inside the anode, inside a vacuum. These machines are not considered a viable approach to net power because of their high conduction and radiation [28] losses. They are simple enough to build that amateurs have fused atoms using them. This design attempts to combine magnetic confinement with electrostatic fields, to avoid the conduction losses generated by the cage. This method confines hot plasma using a magnetic field and squeezes it using inertia. Researchers at Brookhaven reported positive results which were later refuted by further experimentation. Fusion effects were actually produced because of contamination of the droplets. Fusion has been initiated by man, using uncontrolled fission explosions to ignite so-called Hydrogen Bombs. Early proposals for fusion power included using bombs to initiate reactions. A beam of high energy particles can be fired at another beam or target and fusion will occur. This was used in the s and s to study the cross sections of high energy fusion reactions. This was a fusion reaction that was supposed to occur inside extraordinarily large collapsing gas bubbles, created during acoustic liquid cavitation. This is a hypothetical type of nuclear reaction that would occur at, or near, room temperature. Cold fusion is discredited and gained a reputation as pathological science. This approach replaces electrons in the plasma by muons - far more massive particles with the same electric charge. Their greater mass allows nuclei to get much closer and collide more easily, so it greatly reduces the kinetic energy heat and pressure required to initiate fusion. A problem is that muons require more energy to produce than can be obtained from muon-catalysed fusion, making this approach impractical for power generation. The theoretical limit of producing power by such means is a type-2 civilization using a Dyson Sphere. Heating[edit] Gas is heated to form a plasma hot enough to start fusion reactions. A number of heating schemes have been explored: This is basically the same concept as a microwave oven. This is also known as electron cyclotron resonance heating or Dielectric heating. Some of the intermediate hydrogen gas is accelerated towards the plasma by collisions with the charged beam while remaining neutral: Once inside the plasma the neutral beam transmits energy to the plasma by collisions as a result of which it becomes ionized and thus contained by the magnetic field thereby both heating and refuelling the reactor in one operation. The remainder of the charged beam is diverted by magnetic fields onto cooled beam dumps. Antiproton annihilation Theoretically a quantity of antiprotons injected into a mass of fusion fuel can induce thermonuclear reactions. This possibility as a method of spacecraft propulsion, known as Antimatter-catalyzed nuclear pulse propulsion , was investigated at Pennsylvania State University in connection with the proposed AIMStar project. Measurement[edit] Thomson Scattering Light scatters from plasma. This technique can be used to find its density and temperature. It is common in Inertial confinement fusion , [39] Tokamaks [40] and fusors. In ICF systems, this can be done by firing a second beam into a gold foil adjacent to the target. This makes x-rays that scatter or traverse the plasma. In Tokamaks, this can be done using mirrors and detectors to reflect light across a plane two dimensions or in a line one dimension. Langmuir probe This is a metal object placed in a plasma. A potential is applied to it, giving it a positive or negative voltage against the surrounding plasma. The metal collects charged particles, drawing a current. As the voltage changes, the current changes.

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Chapter 5 : Project MUSE - Bibliography

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Chapter 6 : Signal processing for the physical sciences | Royal Society

the jet project and the prospects for controlled nuclear fusion Proceedings of a Royal Society Discussion Meeting held on 12 and 13 March (PEASE, R.S., BICKERTON, R.J., KEEN, B.E., Eds), first published in Philosophical Transactions of the Royal Society.

Philosophical Transactions of the Royal Society of London. JSTOR is a not-for-profit service that helps scholars, researchers, and students discover, use, and build upon a wide range of content in a trusted digital archive. We use information technology and tools to increase productivity and facilitate new forms of scholarship. Series A, Mathematical and Physical Sciences. The stability diagram of a low fi ohmic plasma is discussed. Examples of instabilities driven by toricity and by pressure are given. Results of optimization lead to a scaling law for the maximum fi that can be stably confined. It has not been overcome by experiments so far. It is always of the order of microseconds or less. In such an instability, the motion is fast compared to the resistive and thermal diffusion time through the plasma so that the magnetic field is frozen and the plasma behaves as an ideal, perfectly conducting fluid. The most violent of these instabilities are destructive and they must be imperatively avoided if the plasma is to exist at all for a substantial amount of time. It is easily stabilized by a small amount of toroidal field. Another, slower-growing instability, however, becomes visible. The plasma is deformed in a helix, the pitch-length of which increases as the B. It is a long-wavelength instability as shown in figure 2 on the same straight discharge. When the pitch-length is further increased the plasma becomes grossly stable. Slower-growing instabilities, which are not always destructive to the confinement, can still manifest themselves. Their consequences are nevertheless important, for example, driving turbuk1nce, which increases transport, inducing changes in the magnetic topology, driving global relaxation phenomena. The instabilities that lead to a redistribution of the magnetic I1I-2 This content downloaded from The deformation exponentiates because of the increasing imbalance between the magnetic force and the plasma pressure. Stabilized Z-pinch Be, Bz fields. The force imbalance due to the higher magnetic force inside the kink drives it away from the straight equilibrium. This content downloaded from These so-called resistive instabilities create a braiding of the field lines. The very existence of a tokamak discharge demonstrates that there is an operational range in which there are no fast instabilities and slower-growing instabilities saturate. This presentation is limited to the description of the fastest ideal MHD instabilities and the operational limits introduced by their onset. It has a geometric interpretation. It is the number of times a field line has to turn around the major axis for its image projected on a fixed meridian plane to close on itself. In ohmically heated tokamaks, the current profile is seen to peak spontaneously, which leads to a monotonically increasing q profile from the axis qo to the surface q. The value qo stabilizes around 1, the exact value being still not known with certainty. Such a q profile is the signature of the tokamak. A tokamak equilibrium is characterized by its geometry major radius R and the shape of its minor cross section , the toroidal field, the local current density profile ji or equivalently its q profile and the plasma pressure profile p. TROYON A stable equilibrium corresponds to a minimum of the potential energy, with the proper constraint between the variations of the pressure and of the magnetic field. On the ideal time scale the essential constraint is the freezing of the magnetic field in the fluid. The most convenient way to compute the change in potential energy is to introduce the displacement vector field 4 x, t of the plasma relative to its equilibrium position. When they occur for elongated cross section , they are cured with a combination of passive and active stabilization as in JET. Simple in principle, this stability criterion has turned out to be very difficult to use in toroidal geometry. The difficulty lies in the fact that the plasma can never be better than marginally stable. Straightforward numerical minimization of the potential energy will introduce an error which can be stabilizing or destabilizing and it is then difficult to separate the numerical inaccuracy from an eventual destabilization. Loosely speaking, it is like trying to approximate a flat surface by pieces of curved surfaces. It will never be exactly flat. These difficulties have nevertheless been solved, or at least are well enough understood to be overcome, and there exist now large computer codes Grimm et al. I 98 I; Degtyarev et al. I ; Goedbloed et al. I suitable to study the stability of any toroidal equilibrium to low-n perturbations. For short wavelengths n -X cx an analytic theory has been developed Connor et al. I which leads to an easy test to be carried out on each isobar, the so-called ballooning mode criterion. There remains a problem with intermediate values of n and it is generally assumed, but only verified in a couple of cases, that their behaviour is not different from that of the very low n or very high n. Figure 3 shows the stable region free of any ideal instabilities even in the absence of any conducting shell around the plasma. The right-hand boundary depends sensitively on the current profile. The current profile is a smoothed rectangular profile 11 with q. This configuration would be stable in a straight plasma column. The growth rate is 0. This appears to remain the limit on the current which can flow in the plasma as long as the shear at the edge rate of change of q is not too large. The right-hand boundary closes towards the left while the left boundary moves very slowly to the right. Which n will close in first depends on the pressure profile. The very-short-wavelength modes n -- oo are sensitive to the local pressure gradient and to the local rate of change of q, called the shear. For rounded q profiles with shear varying continuously from the centre to the edge there is a maximum pressure gradient on every surface beyond which the high n modes are unstable. This leads, when the pressure profile is made marginal everywhere, to a maximum value of,l. The origin of this instability can be qualitatively understood. The most dangerous defor- mation of the plasma has an helicity that matches locally that of the magnetic field as well as the periodicity in 0 allows it. This reduces the perturbed magnetic energy term in 7 to a minimum. Simultaneously by coupling various ms the amplitude of the mode is maximized in the region where the last term of 8 W 7 is negative. This is usually on the outside of the torus. Figure 5 shows for, a sequence of JET-shaped equilibria with This content downloaded from Increasing fi increases the growth rate and the mode becomes more global with less internal structure. Each step in fi increases the growth rate by three to four. Peaking of the displacement reveals the location of the singular surfaces. The lowest value of ,B is close to the marginal point. This instability is expected to be hard because it cannot be suppressed by a local adjustment of the profiles. Above this current and up to about 12 MA stability is achieved in a band of fi. This is due to the fact that the pressure increases qa for a fixed total current I, so that I can be further increased without crossing the limit qa t 2. The optimum corresponds each time to a current profile such that q0 t 1. The limiting fi in JET as a function of the current I. Along the interrupted line, qa , 2. A ballooning optimization carried out with a very similar current profile Sykes et al. Newer results obtained on ASDEX have added additional support for the scaling law as well as evidence that the fi limit calculated above may only be reached in a transient state, the steady-state value being still lower von Gierke et al. It is thus necessary to improve on this circular limit. In this respect the JET configuration, with the combination of a small aspect ratio and moderate elongation, is remarkable. The maximum current of 12 MA is about 2. I MHD instabilities, p. Lond A , I Controlled fusion and plasma physics. Europhysics conference abstracts 9F 1 , Europhysics conference abstracts 9F 1 I MHD stability of tokamak experiments with high beta. Europhysics conference abstracts 2, Introduction and Background [pp. Evolution, Status and Prospects [pp. Characteristics and Implications [pp.

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Chapter 7 : Fusion power - Wikipedia

A Fusion Nuclear Science Facility (FNSF) could play an important role in the development of fusion energy by providing the nuclear environment needed to develop fusion materials and components. The spherical torus/tokamak (ST) is a leading candidate for an FNSF due to its potentially high neutron wall loading and modular configuration.

He was talking about the new ideas that were going around about deep inelastic electron scattering experiments at SLAC. I think this was the first evidence for gluons. It all started as an accident of timing. I was in the right place at the right time thinking about neutrino scattering, which was being studied at CERN. I am amazed by how you always manage to find yourself at the crossing of all possible borders â€" not only between theoretical and applied physics, or between economics, education, politics, and science, but also literal ones, like the border of USSR in â€" Lebedev Physical Instituteâ€¦ FIAN. How did that happen? This was not regarded as a suitable subject in the USSR in the s. Virginia was clearly ahead of her time! During your varied career, what have you found to be the key to successful communication between people with different economical, political and scientific backgrounds? The universality of science is the key to communication among scientists with diverse political and cultural backgrounds and views. How do you do it? How do you get things done and avoid disappointment? To cite just one, I worked very hard to get funding for the final stage of the upgrade of LEP the Large Electron Positron collider at CERN , and for an additional year of operation, because there were good reasons to think that it might discover supersymmetric particles this was also one part of the case for building the LHC, Large Hadron Collider. It was ironic and ridiculous. If you could put your Director of Energy Research hat on for this one: This will not be straightforward because the European Court of Justice ECJ is responsible for the adjudication of disputes related to Euratom. The UK has announced that it will no longer accept ECJ arbitration on any matter, but it is hard to see the EU agreeing to anything else. The lack of any form of UK association with Euratom would have very serious consequences for fusion research. In preparation for the operation of ITER, more experience is needed with a mixture of deuterium D and tritium T , the fuels that are almost certain to be required if fusion is ever used as a source of power. Most alarmingly for the UK, Euratom is responsible for nuclear safeguards and movements of nuclear materials it actually owns all non-military materials held by its members , and for overseeing nuclear safety in Europe. Unless alternative arrangements are in place by then, the nuclear power production in the UK will grind to a halt on April 1, Today is a very dramatic time to be speaking about changes in energy system. A lot was said today after your talk â€" was there a question you liked or you wish that you were asked? My own belief is that the transition to low carbon energy now has enough momentum that it will continue whatever Trump does, although it may go a bit slower. Part of the Paris Agreement was to transfer funds to developing countries to help them get away from carbon-based energy, and that will presumably suffer from US withdrawal. I assume that California, which is the sixth biggest economy in the world on its own, is just going to keep going, and not going to pay any attention to Trump. Like Stone Soup, the Paris Agreement depends on voluntary contributions, or at least pledges, but it does not require that everyone does the same thing and the analogy is not complete. In fact, rather than encouraging others to pull out, US withdrawal seems to have strengthened the resolve of China and of the European Union. In the Stone Soup case, everyone puts something in and gets something out of the pot. In the case of de-carbonization, inputs and outputs have been very unbalanced. Germany, for example, poured subsidies into wind and solar energy, which produced a lot of renewable power, in a country where the potential is limited. However, this did not have a big impact on carbon emissions, because of the decision to close down nuclear power, or, as had been hoped, benefit German renewable companies although German machine-tools are used to make solar cells worldwide. But the rest of the world benefitted enormously because the experience of large-scale manufacturing drove down costs.

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Actually, China captured a lot of the solar PV market, and Denmark and others took the lead in wind. As I said, the transition to wind and solar has a momentum of its own, supported by many States. In your opinion, to what extent is the choice between fossil fuels and renewables more a matter of culture or economics? Attitudes are very important. However, in most of the world, economics will determine the speed and extent of the move to renewables. How important is it to get the public more educated, interested and involved in sustainability and the use of renewables? Where do you start? The more the public understands the need to move away from fossil fuels, the better. Most people have probably made up their minds about climate change. Also to reduce international tensions by rebalancing relations between major exporters of fossil fuels Russia, the Gulf States and importers. Public appreciation of these arguments can help speed up the energy transition, but the key is to develop clean alternatives to fossil fuels that are also cheaper. Do you think this is true? Those I know became vegetarians for health reasons or concern about animal welfare. When you spoke of the dire need to decarbonize, you mentioned that one way is to rethink the industrial processes. Do you know if these attempts to rethink it are being implemented at the ITER construction at all? While SESAME is not the highest energy or the brightest synchrotron radiation facility in the world, it will be a good facility that will enable good experiments by a large community which up to now has not had access to a light-source, and someone with the right idea could use it to win a Nobel Prize. In , my colleague Elyce Winters spoke with Eliezer Rabinovici, whom you also mentioned in your talk. Would you like to comment on the various difficulties â€" political, financial, even inclement weather â€" that the project encountered, which you mentioned in your presentation? You would expect some difficulties over a period like that. When the political situation in the Middle East was particularly bad a few years ago, someone asked whether we should give up. My reaction was that the worse the situation, the more we need SESAME, as it shows that people of goodwill can work together to achieve common ends across some of the deepest divides on the planet, in the most dire of circumstances. If we could go back to ITER â€" it is obviously not the project for someone who likes instant results. How do you deal with such a timeline? I was surprised that nobody asked me about the prospects for fusion after my talks here. Let me deal with that unasked question first. The question of reliability will remain unanswered until we try, although operation of ITER will provide clues. The cost of wind and solar power has decreased faster than anyone could have dreamt. I think we need to finish ITER and establish once and for all whether fusion really is a viable option. We will then have to reassess the likely cost of fusion power in the light of the experience gained with ITER and in comparison with the cost of alternatives before deciding whether to go ahead and build a real fusion power station. Your question whether people will be willing to commit to projects with such long time scales is a good one. A similar question arises in high-energy physics. How do you deal with these long-time scales? This issue is not new. During the Middle Ages, people in Europe designed and started building cathedrals, which often took hundreds of years to complete, knowing they would never see them finished. They presumably considered that they were doing it for the glory of God and the spiritual benefit of succeeding generations. Likewise, people may be willing to devote their lives to fusion, or other very long-term projects, with no expectation of seeing them working in their lifetimes, if they are convinced that they may provide a better world for their great grandchildren. On the other hand, people work in high-energy physics to satisfy their intellectual curiosity, and presumably want to live to know the answers to the questions they are addressing. If the timescales get very much longer, I think it will become increasingly difficult to attract people to such fields. I certainly would not have wanted to become Director General of CERN in order to start a project which I knew would not be finished for 50 years. Thank you very much, good luck and hope to see you again at the Center. Llewellyn Smith , Nuclear Physics B14

Chapter 8 : List of Horizon episodes - Wikipedia

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