Latest Challenges Faced in Buclear Physics

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Abstract

Nowadays, after many years of intense research, we know that nuclei are made of positively charged protons and neutral neutrons, together called “nucleons.” Nucleons themselves are also not structure less particles, but are made of quarks, bound together by the strong force, mediated by the gluons. Quarks and gluons are the degrees of freedom to be used when nuclei are investigated with high-energy probes (i.e., with energies higher than the nucleon mass itself). Neutrons in motion are the starting point for everything that happens in a nuclear reactor.

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1. INTRODUCTION

However, in ordinary matter, quarks are confined, and the relevant degrees of freedom are nucleons and eventually mesons. Nuclear Physics (NP) is that field of research dealing with nucleons inside nuclei. The number of protons inside a nucleus corresponds, in neutral atoms, to the number of electrons surrounding the nucleus.

2. NUCLEAR PHYSICS AT SERVICE FOR OTHER FIELDS

Many accelerator experiments are running, or planned to run, with the ultimate goal of measuring neutrino-oscillation parameters, as the neutrino mass hierarchy and the charge-conjugation parity violating phase. These experiments employ nuclear targets, like 16O, 56Fe, 208Pb, or 40Ar, and simple models for the nucleus and reaction mechanism. A grand challenge of NP is to provide an accurate determination of the neutrino-nucleus cross section in a wide energy range, to become accurate inputs for the analysis of experimental data.

3. NUCLEAR PHYSICS INSTRUMENTATION, DETECTION SYSTEMS AND TECHNIQUES

Nuclear physics (NP) research seeks to understand the structure and interactions of atomic nuclei and the fundamental forces and particles of nature as manifested in nuclear matter. Nuclear processes are responsible for the nature and abundance of all matter, which in turn determines the essential physical characteristics of the universe. The primary mission of the Nuclear Physics (NP) program is to develop and support the scientists, techniques, and facilities that are needed for basic nuclear physics research and isotope development and production. Attendant upon this core mission are responsibilities to enlarge and diversify the Nation's pool of technically trained talent and to facilitate transfer of technology and knowledge to support the Nation's economic base.

Nuclear physics research is carried out at national laboratories and accelerator facilities, and at universities. The Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF) allows detailed studies of how quarks and gluons bind together to make protons and neutrons.

In an upgrade currently underway, the CEBAF electron beam energy will be doubled from 6 to 12 GeV. The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL) is forming new states of matter, which have not existed since the first moments after the birth of the Universe; a beam luminosity upgrade is currently underway. NP is supporting the development of a future Facility for Rare Isotope Beams (FRIB) currently under construction at Michigan State University. The NP community is also exploring opportunities with a proposed electron-ion collider.

4. SUITABILITY CRITERIA FOR NUCLEAR POWER STATIONS

The NRC issues regulatory guides to describe to the public methods that the staff considers acceptable for use in implementing specific parts of the agency's regulations, to explain techniques that the staff uses in evaluating specific problems or postulated accidents, and to provide guidance to applicants. Regulatory guides are not substitutes for regulations and compliance with them is not required. Methods and solutions that differ from those set forth in regulatory guides will be deemed acceptable if they provide a basis for the findings required for the issuance or continuance of a permit or license by the Commission.

5. ADVANCING NUCLEAR MEDICINE THROUGH INNOVATION

Nuclear medicine is a highly multi-disciplinary specialty that develops and uses instrumentation and radiopharmaceuticals to study physiological processes and non-invasively diagnose, stage, and treat diseases. A radiopharmaceutical is either a radionuclide alone, such as iodine-131 or a radionuclide that is attached to a carrier molecule (a drug, protein, or peptide) or particle, which when introduced into the body by injection, swallowing, or inhalation accumulates in the organ or tissue of interest. In a nuclear medicine scan, a radiopharmaceutical is administered to the patient, and an imaging instrument that detects radiation is used to show biochemical changes in the body.

Nuclear medicine imaging in contrast to imaging techniques that mainly show anatomy (e.g., conventional ultrasound, computed tomography [CT], or magnetic resonance imaging [MRI]), can provide important quantitative functional information about normal tissues or disease conditions in living subjects. For treatment, highly targeted radiopharmaceuticals may be used to deposit lethal radiation at tumor sites.

6. LITERATURE REVIEW

Muhammad Adil Khattak (2017) Sitting Consideration for Nuclear Power Plant The purpose of this research is to study in detail about the site selection process in nuclear power plant (NPP) construction. There are various factors that contribute to the site selection which involves in-depth investigation and detailed evaluation before the site is being finalized and proposed. There are two main objectives in sitting of NPP; ensuring the technical and economic feasibility of the plant and minimizing potential adverse impacts on the community and environment. Geographical environment also plays an important role in sitting of NPP where The source of water should be abundance. Country requirement for sitting of NPP would be different for every country where they are controlled by their own regulatory bodies.

Laura E. Marcucci (2018) there are more than 250 isotopes on Earth, and more than thousands have been synthesized in laboratories, although most of them are unstable. The nuclear chart, where these isotopes are classified according with the number of protons and neutrons, is definitely much more complex than the more familiar Periodic Table! It is then clear why NP is still nowadays a fascinating field of research, with many open questions, whose answers will advance our *basic knowledge of Nature*. Some of these questions are listed in section 2, the grand challenges in NP for the next 20 years or so.

SIMIC Zdenko WASTIN Franck (2016) During the five years after the major accident in the Fukushima Daiichi nuclear power plant a number of reports from major international institutions (like IAEA and OECD NEA) and research organizations have drawn conclusions and lessons to learn from this terrible accident. These reports are the result of expert and scientific analyses carried out during the five years and they present ideal sources for both understanding what has happened and what can be learnt in order to avoid and mitigate effects from such events in the future. From a wider perspective it is also interesting to analyze the impact of nuclear accidents on research and development (R&D) activities. This paper analyses the published nuclear energy (NE) related research over the last 50 years, with focus on three major nuclear accidents Three Mile Island (TMI), Chernobyl and Fukushima.

Kemal İhsan Kılıç (2016) the basic concepts introduced in bottom up manner, starting from the basic physics of the isotopes. Sources and effects of the ionizing radiation presented and discussed in a detailed manner. Important concepts are explained through illustrations and figures. Basic claims are supported with the scientific data from authorities. Information from diverse disciplines and researchers is synthesized into instructive survey

McCombie (2016) the technology is improving and the cost of the electricity generation is becoming cheaper. Extensive overview on the reactor technologies and the prospects of the industry can be found in. On the efficiency of the energy another comparison is given. Energy Return on Investment (EROI) is a tool introduced by J. Conca, (cited in in which ratio of energy returned to energy invested over the life cycle of the energy source is considered. The superiority of the nuclear power can be seen from. Further analysis and assessment can be found.

7. SPECIALIZED TARGETS FOR NUCLEAR PHYSICS RESEARCH

Grant applications are sought to develop specialized targets, including:

1. Polarized (with nuclear spins aligned) high-density gas or solid targets capable of withstanding high electron or proton beam currents beyond the current state of the art; polarized 3He targets, especially novel high-pressure circulating gas concepts matching the next generation of high luminosity electron and photon beam experiments;

2. Very thin windows (<100 micrograms/cm^2 and/or50% transmission of 500 eV X-rays) for gaseous detectors, for the measurement of low-energy ions; and

3. A positron-production target capable of converting hundreds of kilowatts of electron beam power (10 MeV at 10 mA) over a sufficiently short distance to allow for the escape of the produced positrons. Of particular interest would be moving and/or cooled high-Z targets of uniform, stable thickness (2-8 mm), which may be immersed in a 0.5-1.0 T axial magnetic field.

Grant applications also are sought to develop the technologies and sub-systems for the targets required at high-power, rare isotope beam facilities that use heavy ion drivers for rare isotope production. Targets for heavy ion fragmentation and in-flight separation are required that are made of low-Z materials and that can withstand very high power densities and are tolerant to radiation.

Finally, grant applications are sought to develop techniques for:

1. Production of thin films (in the thickness range from a few μg/cm^2 to over 10 mg/cm^2) for charge state stripping in heavy-ion accelerators; and

2. Preparation of targets of radioisotopes, with half-lives in the range of hours, to be used off-line in both neutron-induced and charged-particle-induced experiments.

8. NUCLEAR FISSION

Fission may take place in any of the heavy nuclei after capture of a neutron. However, low-energy (slow or thermal) neutrons are able to cause fission only in those isotopes of uranium and plutonium whose nuclei contain odd numbers of neutrons (*e.g.* U-233, U-235, and Pu-239). Thermal fission may also occur in some other transuranic elements whose nuclei contain odd numbers of neutrons. For nuclei containing an even number of neutrons, fission can only occur if the incident neutrons have energy above about one million electron volts (MeV). (Newly-created fission neutrons are in this category and move at about 7% of the speed of light, while moderated neutrons move a lot slower, at about eight times the speed of sound)

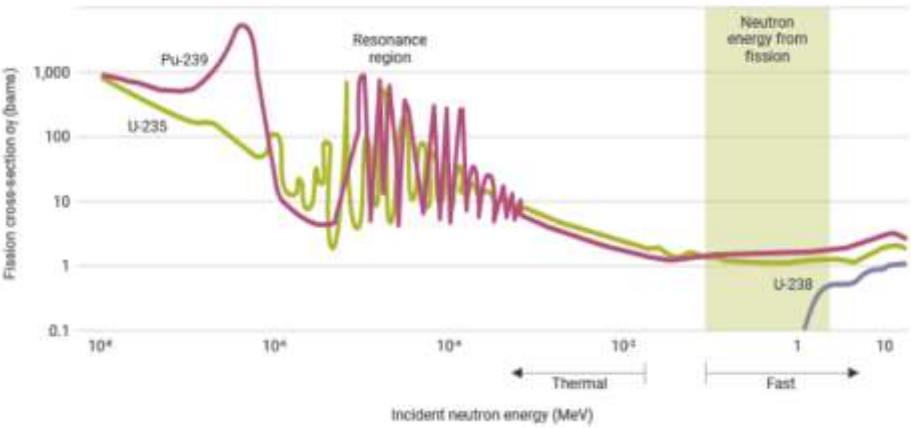

Figure 1.1: Neutron cross-sections for fission of uranium and plutonium

9. NUCLEAR FISSION – THE PROCESS

Using U-235 in a thermal reactor as an example, when a neutron is captured the total energy is distributed amongst the 236 nucleons (protons & neutrons) now present in the compound nucleus. This nucleus is relatively unstable, and it is likely to break into two fragments of around half the mass. These fragments are nuclei found around the middle of the Periodic Table and the probabilistic nature of the break-up leads to several hundred possible combinations. Creation of the fission fragments is followed almost instantaneously by emission of a number of neutrons (typically 2 or 3, average 2.45), which enable the chain reaction to be sustained.

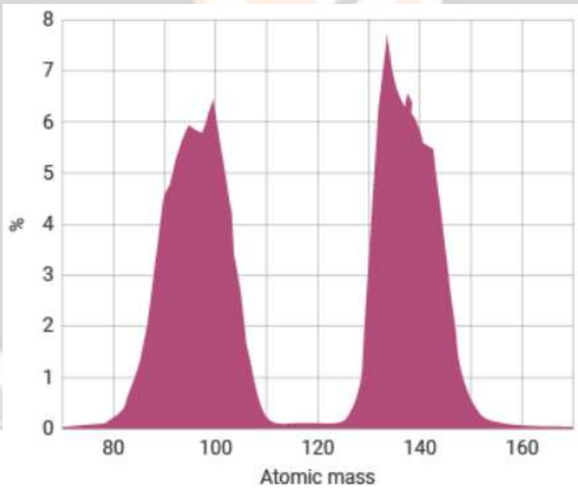

Figure 1.2: Distribution of fission products

However, conservation laws require the total number of nucleons and the total energy to be conserved. The fission reaction in U-235 produces fission products such as Ba, Kr, Sr, Cs, I and Xe with atomic masses distributed around 95 and 135. Examples may be given of typical reaction products, such as:

U-235 + n ===> Ba-144 + Kr-90 + 2n + about 200 MeV

U-235 + n ===> Ba-141 + Kr-92 + 3n + 170 MeV

U-235 + n ===> Zr-94 + Te-139 + 3n + 197 MeV

In such an equation, the number of nucleons (protons + neutrons) is conserved, *e.g.* 235 + 1 = 141 + 92 + 3, but a small loss in atomic mass may be shown to be equivalent to the energy released.

10. CONCLUSION

Compared to air and nuclear physics problems situation is better in the case of nuclear physics, if the amount of nuclear is considered. Yet the hazard that comes from nuclear physics and the persistence of the contamination is greater when all things are equal. It is in the nature of radioactive elements that they are rich in possibilities and also rich in hazardous ways. Except the nuclear reactor accidents and medical treatment, the highest radiation exposure comes from the natural sources which cannot be controlled easily. Through precautionary efforts and regular measurements certain degree of protection can be provided for natural radiation sources. But in the case of reactors, redundancies (backup safety systems) should not be avoided for safety.

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