Introduction and Disclaimer

These mock examination questions span diverse disciplines and are designed for your practice in preparation for the International Research Olympiad (IRO) 2024. Endeavor to answer them to the best of your ability, utilizing this opportunity to enhance your skills and knowledge. For additional practice, it is advisable to engage in extensive reading of various papers; such efforts will contribute to a more comprehensive and nuanced understanding of the subject matter.

Try your best, and good luck! -International Research Olympiad 2024

Mock Examination Answer Key 4
Bolded answers are correct.

Paper 4: High Energy Physics

Question 1

Question: The ATLAS experiment at the Large Hadron Collider was crucial in the observation of a new particle. What is the primary role of the ATLAS detector in this context?

a.) **To detect and measure the energy of particles resulting from proton-proton collisions.**

- **The ATLAS detector is designed to observe the results of collisions, such as those between protons, by detecting the particles created and measuring their energies.**

b.) To generate high-energy proton beams for collision experiments.

- The acceleration and generation of proton beams are functions of the LHC's accelerator complex, not the ATLAS detector.

c.) To provide theoretical predictions for particle interactions.

- Theoretical predictions are formulated by physicists using mathematical models, not directly by the ATLAS detector itself.

d.) To focus on astrophysical observations outside the LHC.

- ATLAS is a particle physics experiment and does not engage in astrophysical observations.

Question 2

Question: In the search for the Higgs boson, one of the key concepts is its ability to endow other particles with mass. Based on the paper, what property of the Higgs boson makes it unique compared to other elementary particles?

a.) It is the only particle with an infinite mass.

- Particles cannot have infinite mass; the Higgs boson's mass is finite and measurable.

b.) It is the only particle that interacts with the gravitational force.

- All particles with mass interact with gravity, not just the Higgs boson.

c.) **It has no spin, electric charge, or color charge.**

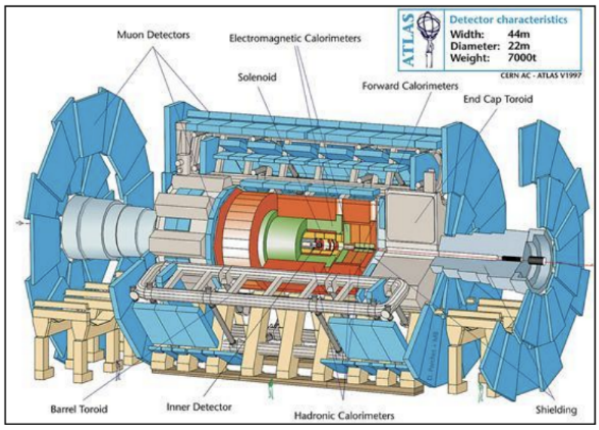
- **The Higgs boson is unique because it is a scalar particle with no spin, electric charge, or color charge, differentiating it from other elementary particles.**

d.) It is the smallest particle known to exist.

- The concept of size is not well-defined for point-like particles in quantum mechanics, and the Higgs boson's uniqueness is not related to its size.

Question 3

Question: The ATLAS detector, used in this experiment, is a complex apparatus designed to observe a variety of particle interactions. If a schematic diagram of the ATLAS detector was provided, which component is responsible for measuring the momentum of charged particles?



a.) **The inner detector system, utilizing layers of sensors.**

- **The inner detector system of the ATLAS detector is equipped with various types of sensors that track the paths of charged particles, allowing for the measurement of their momentum.**

b.) The calorimeters, designed to measure the energy of particles.

- Calorimeters measure the energy of particles when they are stopped and absorbed, not their momentum.

c.) The magnet system, primarily for bending particle trajectories.

- While the magnet system bends charged particles' paths, it is the inner detector that measures these deflections to compute momentum.

d.) The outer muon spectrometer, for identifying muons specifically.

- The muon spectrometer identifies muons and measures their momentum but is not the primary component for measuring the momentum of all charged particles.

Question 4

Question: In the paper, the data visualization of the decay channels of the new particle plays a critical role. Suppose you are shown a graph depicting the decay of this particle into two photons. What does this specific decay channel signify about the properties of the new particle?

a.) It suggests the particle is a type of quark.

- Quarks do not typically decay directly into photons, as they are subject to the strong nuclear force, not just electromagnetic interactions.

b.) **It indicates the particle has a strong interaction with electromagnetic forces.**

- **The decay into two photons suggests that the particle can interact with the electromagnetic force, as photons are the force carriers of electromagnetism.**

c.) It shows the particle has a direct interaction with dark matter.

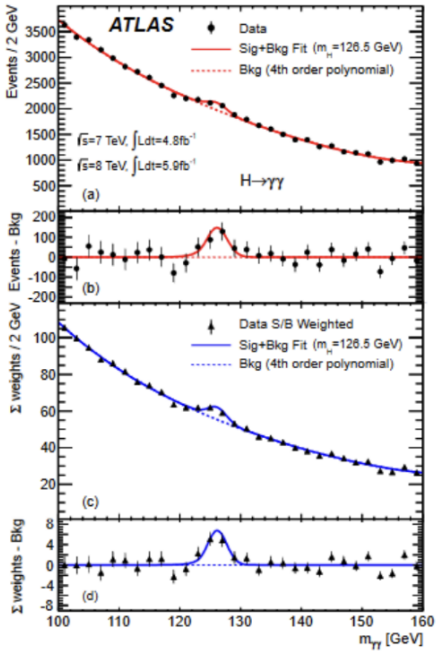
- Decay into photons does not provide direct evidence of interaction with dark matter, which does not typically involve electromagnetic decay channels.

d.) It implies the particle is primarily involved in gravitational interactions.

- The decay into photons is more indicative of electromagnetic interactions rather than gravitational ones.

Question 6

Question: The paper discusses the significance of the mass of the newly observed particle in confirming its identity as the Higgs boson. Imagine you are shown a plot displaying the invariant mass distribution of a number of particle decay events. The plot shows a distinct peak at around 125 GeV. What does this peak in the distribution signify in the context of the Higgs boson search?



a.) It represents the collective mass of all particles produced in the LHC.

- The invariant mass peak is not about the collective mass but rather is indicative of the mass of a particular particle type produced in the collisions.

b.) It indicates the energy level at which quarks are formed from gluons.

- The formation of quarks from gluons is part of the strong nuclear interactions and not directly related to the invariant mass peak in Higgs boson searches.

c.) **It signifies a common mass value where a significant number of events cluster, hinting at the mass of the new particle.**

- **The distinct peak in the invariant mass distribution suggests a resonance at that mass value, which is consistent with a particle like the Higgs boson being produced.**

d.) It shows the maximum energy level achieved by the LHC during the experiments.

- The peak reflects a particle's mass resonance, not the maximum energy of the collider itself.