Comparison of Detection Schemes for Different Types of Dark Matter Candidate

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Abstract. Dark matter is one of the most concerning topics in frontier physics today, through continuously exploring scientific research personnel, people gradually have a certain knowledge of the dark matter, about a potential way of detecting dark matter particles. However, the researchers found that still lack of unified cognition, therefore the research topic of this article is to compare different state-of-art ways and scenarios to explore the dark matter particles. To be specific, direct detection, the way in indirect detection and the way collision detection. By comparing the merits and demerits of historical dark matter detection methods, this study tries to summarize more effective ways of observing dark matter. According to the analysis, the most successful scenarios that has been carried out right now is the direct detection. These findings provide useful information for directing future research that could improve the current conventional particle model or, as proposed by Einstein a century ago, open up new physics horizons. These results shed light on guiding further exploration of searching dark matter.

Keywords: Dark matter; Detection; WIMPs; PandaX; CDEX.

1. Introduction

Astronomers of the 19th century also discussed a kind of dark matter exists, the levy that found a dark after the precession of the mercury planet of interference, then the invent on of astronomical photography, allowed scientists to notice that the stars in space distribution are not uniform, people had to discuss the space is dark because rare or have a substance to absorb the light of the stars. Lord Kelvin then made the first attempt to estimate the number of dark matter objects in the universe, using the relationship between velocity dispersion and system size. Poincare was so impressed by Kelvin's ideas that he explicitly mentioned dark matter in 1906, arguing that it was much less abundant than luminous matter. In addition, in 1915 astronomers, ERNST developed a model that also concluded that there could not be large amounts of invisible matter in the universe, and their work opened the new path to measuring local dark matter densities. Subsequently, Zwicky first used the force law to determine the mass of galaxy clusters, which led him to the surprising conclusion that there is a lot darker matter than luminous matter. The dark matter came into view, and people began to study it for a long time.

Hisano and his team use the supersymmetric (SUSY) model to search the dark matter [1]. At present, there are dozens of direct detection experiments of dark matter being carried out or planned in the world. China is also carrying out two direct detection experiments in Jinping deep earth laboratory, Sichuan Province, PandaX, and CDEX.

Graham and Rajendran use nuclear magnetic resonance and the spin precession method is used to study the frequency of Axion dark matter and the coherence effect of classical dark matter field [2]. The parameter space detected by these techniques far exceeds the limit of astrophysics, and expands the method of finding ultralight particles. Easther, et al. try to use the Minimal Supersymmetric Standard Model (MSSM) [3]. Bae, et al. eschew fine-tuning from the electroweak and QCD sectors of supersymmetry (natural supersymmetry or SUSY), and invoke the Kim-Nilles solution to the SUSY μ problem, almost 90%~95% of axion are expected to be dark matter [4].

In order to provide a clear direction for the detection of dark matter, this paper mainly discusses the advantages and disadvantages of various dark matter detection in the past. The rest part of the paper is organized as follows. The Sec. 2 will describe the basic part of the dark matter. The Sec. 3

will discuss about the direct detection. The Sec.4 will talk about the collision detection. The Sec.5 will compare the two plans to probe the dark matter. The Sec. 6 will summarize and make a wish about the future of the dark matter.

2. Description of the dark matter

The two main contenders for dark matter are the WIMP and Axion, which are stable particles with masses and interaction strengths around the electroweak scale and known residual abundances obtained via thermal decoupling. WIMPs should essentially be color- and electro-neutral, staying out of strong interactions and electromagnetic fields. Although neutrinos do not participate in electromagnetic interactions or strong interactions, they do belong to the category of "hot dark matter. In this case, it is not enough to make up the majority of dark matter because of their near-lightspeed motion in the universe. WIMPs must be new physical particles that go beyond the Standard Model because there are no particles in the Standard Model of particle physics that is currently known to man that satisfy both of these requirements. Existing theories predict wimps such as the neutralino, the lightest supersymmetric partner particle in the supersymmetric model [5], the smallest Kaluza-Klein excited state particle in the extra dimension theory, and T-odd particles in the Little Higgs model.

Axion, a very light neutral particle connected to charge conjugation-parity inversion joint symmetry breaking in strong interactions, is another contender for dark matter. Axions interact with one another through incredibly weak forces, making it impossible for them to be in thermal equilibrium with background radiation. This means that they cannot obtain residual abundance through thermal decoupling, but they can transform into cold dark matter through vacuum state breaking.

WIMPs refer to weakly interacting heavy particles [6]. Before schoalrs predicted that dark matter might be composed of wimps, it was thought that dark matter might be composed of a large number of neutrinos. Nevertheless, it must be verified that neutrinos must have mass.It takes painstaking investigation to determine the mass of Neutrino [7]. Neutrino emissions from nuclear reactions in the reactor are one of the tests, as is the determination of whether the neutrinos' course has changed as a result of their distance from the reactor growing. If the change is real, it can only be explained by neutrino decay, which releases energy while converting neutrinos into other types of particles. An element must meet one or more requirements, including mass, in order to display this decay trait. The conclusion is that neutrinos must have mass if they are actually disintegrating. Although it is feasible to precisely measure neutrinos' masses through more meticulously planned tests, at least now reseachers are aware that neutrinos can be created in their natural condition. If neutrinos have mass, then at least some of the universe's dark matter may be made up of them.

3. Direct Detection

The lightest neutralino converts into almost a pure Wino or Higgsino state in the case where one mass parameter is substantially larger than the other. The importance of the loop-level processes increases as a result. The elastic scattering cross section for generic electroweak-interacting DM particles is assessed in the earlier work, where the loop-level effective couplings are calculated. While pure Higgsino is represented by $n = 2$ and $Y = 1/2$, pure Wino is represented by $n = 3$ and $Y = 0$. As shown in Fig. 1, the loop-level contributions are significant when the DM-particle mass is significantly greater than that of weak bosons, according to the previous findings [8].

If Axion can solve the strong CP problem, the aforementioned interaction "must exist," which is one of its appealing properties. Also providing a limit is the coupling constant, which describes the strength of this connection. If we are able to construct a detector with adequate sensitivity, the detector will be able to produce a clear signal if the axle's mass falls within a predetermined range. The mass of the axle may not be within this range if one is unable to detect this "pointer signal," according to this theory. The search area can then be gradually reduced by scanning until one locates the axle.

A few days ago, Yuan Qiang, a researcher from Zijinshan Observatory of the Chinese Academy of Sciences, cooperated with Ge Shaofeng, an associate professor of Shanghai Jiaotong University, Liu jianglai, a professor, and Zhou Ning, a special researcher, to propose a new type of cosmic ray to boost the diurnal effect of dark matter. According to research, the interaction between dark matter and nucleons not only makes it possible for human detectors to directly detect the recoil force of dark matter and nucleons, but it may also scatter cosmic rays and non relativistic dark matter, causing it to become more energetic. The propagation of dark matter flux on the planet will be attenuated if the dark matter nucleon scattering cross section is large enough, leading to a strong diurnal variation. This diurnal modulation offers yet another standout characteristic for the direct detection of cosmic ray boosted sub GeV dark matter in addition to signals with larger recoil energy. The resulting effect can assist direct detection studies be more sensitive in low-quality regions and can produce a distinctive dark matter collision signal that can be used to identify dark matter from background. A sketch of the interactions between WIMPs and nucleus is shown in Fig. 1

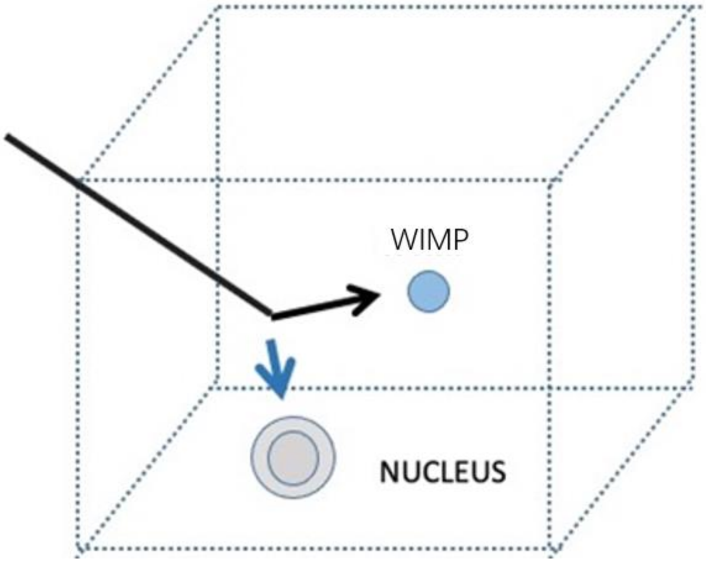

Fig. 1. A sketch of interaction between WIMPs and nucleus

As illustrated in Fig.2, this gadget, called Pandax, may be found in the Shanghai Jiaotong University lab in China [9]. The apparatus contains 500kg of liquid xenon. It also has a "net" that is comparable to twice the lux team's sensitivity over a 15-year period.

Dark matter will collide with liquid xenon and produce a faint signal with a precision of up to 2.7×10^{-46}. The gadget will then pick up the iffy signal. However, nothing will happen after 100 days of waiting—not even the anticipated signal. The theoretical cap on dark matter will be further reduced as a result of this finding. The detection window will be made even smaller because this "net" is still too thin to detect dark matter.

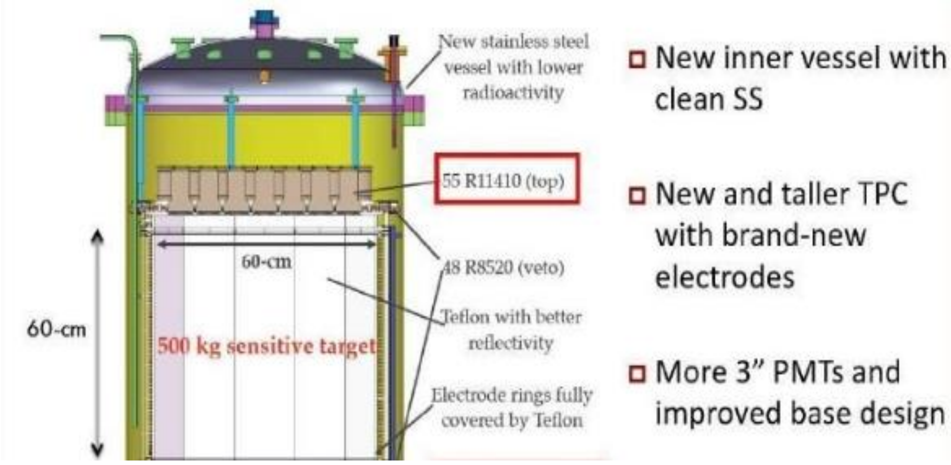

Fig. 2 A sketch of Pandax.

4. Collsion Detection

Only the energy in the center of mass system is the effective energy of particle interaction when the collider bombards the stationary target (particle) with high-energy particles, and this energy only makes up a portion of the total energy of particles in the laboratory system. If a particle strikes a target with energy E, the mass system's energy operating on that same particle inside the target is approximately (E is the rest energy of the particle). However, if there are two energies for E in comparison to the same high energy particle beam collisions, the heart energy, which is around 2 E, meaning particle energy, are available to all interactions. It is evident that as E_0 increases, the proportion of energy used in that part of the interaction between the energies will be more and more tiny, which is to accelerate the particles of energy utilization efficiency is more and more low [10]. The sketch of the dark matter interactions is given in Fig. 3.

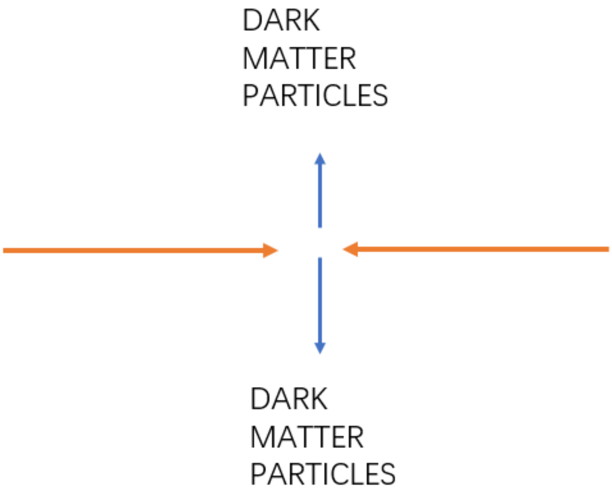

Fig. 3 A sketch of dark matter particles interaction.

The way that the Large Hadron Collider search for evidence of the dark matter created in proton collisions is given in Fig. 4. The so-called loss of lateral momentum, which occurs when dark matter particles collide, is its primary characteristic. The momentum of the particles that can be observed by the LHC detector are added up in order to locate this feature, and any missing momentum is then calculated. The whole amount of momentum ought to be 0. If the total momentum after collision is not zero, it may be because undetected dark matter particles remove the remaining momentum required to make the total momentum zero.

The Fig. 4 depicts an Atlas detector event that lacks lateral motion. 268 GeV (red dashed line on the opposite side of the detector) photons with a missing lateral momentum are balanced with 265 GeV (yellow bar) photons with a lateral momentum. One of the seven experimental detectors provided for the Large Hadron Collider (Atlas) is a toroidal LHC device. It was constructed with the express purpose of observing high-quality particles.

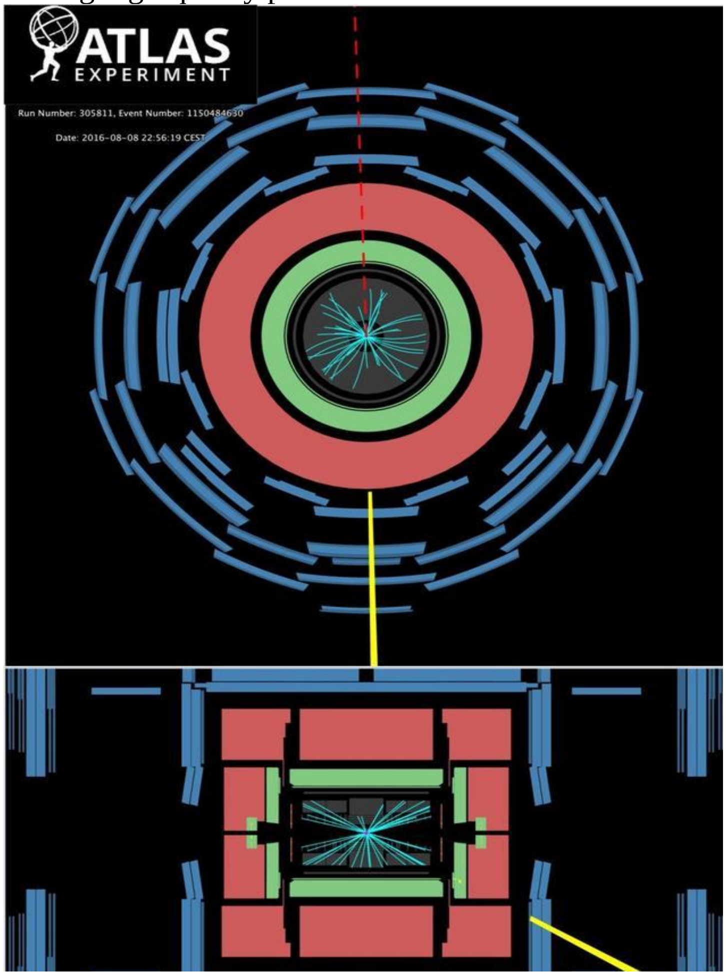

Fig. 4 The sketch of dark matter detection based on LHC.

Two of the LHC's primary investigations are based on momentum loss. One kind is influenced by the so-called "new" physical model, such as the supersymmetry (SUSY) model. In the supersymmetric model, the standard model's description of a known particle is paired with a supersymmetric particle that shares half of the other party's quantum feature, called spin. Furthermore, in many supersymmetric models, the largest supersymmetric particle with weak interactions is the lightest supersymmetric particle (wimp). Wimp is one of the most appealing candidates for dark matter since they can produce the vast majority of dark matter that is now present in the cosmos. A pair of dark matter "leptons" and/or a "spray" of particles, collectively known as WIMP, will be searched for in order to recover their lost momentum. [11]

5. Comparison

The first direct detection is now the most promising, and every nation has established a national subterranean laboratory. However, according to the research, background noise continues to be a major roadblock for the project. On account of the influence of dark matter particles was only marginal, it is ideal for individuals who can effectively block out the majority of cosmic background noise. The use of this class, such as the CERN collider, is too expensive. Once there is no clear direction, the plan is improbable for a long period of time. This frequently applies to individuals when they are needed to accurately regulate the high-energy interval, despite the second scheme's seeming simplicity in principle and the history of new materials, e.g., the higgs particle, which was discovered to be unable to escape the high speed machine.

6. Conclusion

In conclusion, this paper discusses the detection of dark matter like axion and WIMPs mainly based on the model of SUSY. This approach offers the highest likelihood of success from the standpoint of the direct discovery of dark matter, and it also responds well to a number of the leading candidates for dark matter. The other way of creating dark matter in the lab using the Collider (CERN) is more rigorous, yet it still fails to be filtered out in more than ten national laboratories located deep underground throughout the globe. The ultra-high energy level is a hurdle that people have not yet overcome, despite the fact that many experimental data point to hope for this project's future. According to the comments above, the research has not produced any additional findings. It is hoped that advances in human research and technology may accelerate the search for dark matter in the future. In the future, physics, engineering, and astronomy researchers aim to benefit from the research on dark matter. Overall, these results offer a guideline for dark matter detection.

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