

Status of the Laser Isotope Separation (LIS) of ^{48}Ca for CANDLES

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Abstract

A large amount of double beta decay nuclide is required for the search for neutrinoless double beta decay ($0\nu\beta\beta$). CANDLES employ ^{48}Ca due to the outstanding Q-value (4.23 MeV) among double beta decay nuclides [1]. Laser isotope separation (LIS) is introduced aiming for large-scale production of ^{48}Ca .

Keywords: Laser Isotope Separation, Calcium-48, Isotope Separation, Enrichment

1. Introduction

The study of neutrinoless double beta decay ($0\nu\beta\beta$) using ^{48}Ca plays a vital role in addressing key questions in physics, such as the origins of the matter-dominated universe and the possible violation of lepton number conservation. However, the study of this exceedingly rare phenomenon requires a ton-scale quantity of ^{48}Ca , which has a natural abundance of just 0.187%. The production of ^{48}Ca is expensive, estimated at approximately \$1,000,000 per gram. This high cost is primarily due to the lack of a gaseous compound, which complicates the isotope separation process required for large-scale production. Laser isotope separation (LIS) is a promising method for enabling the efficient and cost-effective production of ^{48}Ca , thus addressing one of the key challenges in this area of research.

2. Laser Isotope Separation for ^{48}Ca

Calcium absorbs light at a wavelength of 422.792 nm, with ^{48}Ca exhibiting an isotope shift of ~800 MHz relative to ^{44}Ca . This allows a single-frequency laser to selectively separate ^{48}Ca from other isotopes. [2]. The requirements for mass production consist of the development of an atomic beam generator, laser irradiation unit, collection system, and monitor and control system [3]. By utilizing multiple slave lasers, a high-power laser system can be realized, enabling an efficient separation of ^{48}Ca and boosting the production rate. The spatial distribution of the calcium atomic beam was measured using time-of-flight (TOF) analysis. The displacement of ^{48}Ca was 3.84 ± 0.83 mm, while no displacement was observed for ^{40}Ca , and ^{44}Ca . A new design of the main chamber consisting of six ports irradiation unit is proposed aiming to scale up to 2 mol/year.

3. Conclusion

In conclusion, the adoption of laser isotope separation (LIS) for the large-scale production of ^{48}Ca shows significant promise, with the potential to achieve production rates of up to 2 mols per year. Plans to scale this process to a target of 300 kg per year are being explored, and further advancements are anticipated shortly.

References

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