# An approach for measuring the interaction between anti-neutron and CsI based on BESIII

[一种基于BESIII实验的反中子和碘化铯相互作用的测量方案]

## Abstract

[本文提出一种测量反中子与碘化铯相互作用的新想法，在正负电子对撞机的束流管附近加入碘化铯材料的靶物质。通过挑选与碘化铯相互作用的事例，可以测量相互作用的相关参数。此外，我们基于BESIII实验进行了一些模拟研究，给出了加入靶物质后，按照现在Geant4的参数，可以获得的击中靶物质的反中子的数量和质量。相似的方法可以用在其他实验上研究强子与物质的相互作用，也可以进行一些超子相关的研究。]

In this paper, a new idea for measuring the interaction between antineutron and cesium iodide(CsI) is proposed. CsI is added out of the beam pipe of the electron positron collider. By selecting anti-neutrons which interacted with CsI, the parameters related to the interaction can be measured more accurate. Furthermore, some simulation studies based on BESIII experiment is applied, which show the quantity and quality of anti-neutrons that hit the CsI according to the current parameters in Geant4. Similar methods can be used in other experiments to study the interactions between hadrons and matter as well as for some hyperon-related studies.

Keywords: BESIII, Anti-neutron, Cesium iodide, Jpsi

## Introduction

[研究反中子的物理意义，模拟的物理意义]

Due to electric neutrality, hadrons cannot be generated in the drift chamber

[目前BESIII实验电磁量能器由CsI组成，相互作用参数测量不准确，导致量能器模拟和数据不一致]

Cesium iodide has higher luminous intensity and higher luminescence, Small radiation length and stable chemical property. It is widely used in the electromagnetic calorimeter of high-energy physics experiments. Better energy resolution can be obtained especially low energy. The data of the interaction between antineutron and CsI is insufficient, resulting in the simulation of electromagnetic calorimeter

[使用抽样或深度学习方法可以跳过Monte Carlo过程，提供物理分析需要的数据，但是存在一些局限]

To solve this problem, there are two main ideas. The first one is to use the data-driven methods to extract useful information from the data and directly generate the energy deposition of the detector or the features required for physical analysis. Such methods are model-independent and the impact of missing parameters of interactions can be bypassed. [data-driven方法文献综述] This kind of method has some limitations, when there is any change in the detector, the model may be no longer in force and need to be retrained or fine tuned. Mean while if more detector information needs to be generated, such as the energy depositions of each crystal in the shower, the deep generation models must be used. [GAN或Flow] These models are less stable in training and using, especially for GANs. The second is to find ways to measure the interaction between antineutron and CsI directly, that is, add a target material in the detector as a target. After putting these parameters back into Monte Carlo, we can expect the simulation to be more accurate

[文章结构]

In this paper, a new idea for measuring the interaction between antineutron and cesium iodide(CsI) is proposed. In section 3, the BESIII experiment is introduced, the method of adding additional CsI out of the beam pipe is described, and finally briefly introduced how to select anti-neutrons which interacted with CsI. In section 4, some simulation studies are applied, which give the quantity and quality of anti-neutrons that hit the CsI according to the current parameters in Geant4. Finally, in section 5, possible improvements of experimental design and expansion of research area is discussed.

## Experimental dsign

[BESIII实验简介，物理目标，探测器结构，能量点等]

[束流管外加入物质的方案，材料，厚度，长度，覆盖角度]

The outermost part of the beam pipe is composed of a beryllium tube, which radius is 33.7mm, and is 296mm long. And the innermost part of MDC is a carbon fibre layer with radius of 59.2mm. The gap between beam pipe’s outer beryllium tube and MDC’s inner carbon fibre layer is filled with air. Adding matter here nether affect the beam flow nor the detector. The material we choose for target is CsI, which molecule has one cesium atom and one iodide atom inside, and density is 5.91g/cm2. The CsI is made into a tube shape, has the same length as the outer beryllium tube, and pastes on the outer beryllium tube. The thickness of CsI is the most important parameter that affects the antineutron source. On the one hand, thicker CsI can make more anti-neutrons interact with it, increase the number of samples, and improve the measurement accuracy. On the other hand, thicker CsI at the same time reduces the efficiency and resolution of tag particles, thus reducing the resolution of the recoil calculation, that is, the resolution of anti-neutrons. For this reason, the determination of thickness is actually to trade off the quantity and quality. In section 4, the influence of thickness is mainly studied.

[如何选出与物质相互作用的反中子]

The BESIII experiment has already generated more than 10 billion Jpsi events, there were around 20 million Jpsi decayed to p+pi-nbar while the decay fraction of this physical process is (2.12±0.009)x1e-3. By setting various conditions include number of charged track, position of vertex, PID possibility, recoil mass and energy deposition in EMC, etc., one can obtain the dataset of anti-neutrons with more than 99% purity. The conditions to select anti-neutrons intersected with additional CsI out of the beam pipe are basically the same, while an additional condition need to be added, which is some charged tracks excluding p+ and pi- need to intersect in CsI.

## Study of simulated data

[研究模拟数据的意义]

The ultimate goal of our design experiment is to produce an anti-neutron source, so it makes sense to know the quantity and quality of anti-neutrons. As mentioned in the previous section, quantity means how much anti-neutrons the source can produce and the efficiency of selecting process, quality means the resolution, include momentum resolution and angle resolution, both important for the following physical analysis. In Geant4, the simulation of p+ and pi- are trustworthy, so the impact of adding CsI can be determined accurately. On the contrary, for the interaction between anti-neutron and CsI, the wrong EMC simulation results tell us that the simulation is unreliable, nonetheless, we can get a rough result by comparing the interactions between anti-neutron with beam pip and CsI. Although not accurate enough, it can still provide some useful information.

[模拟软件版本，方案等]

Throughout the study, BOSS7.0.5 is used for simulation and reconstruction. This is a sufficiently stable version. The same additional CsI need to be added in the simulation and reconstruction. In the simulation, it needs to be declared when defining the detector structure. And in the reconstruction, it needs to be added before Kalman fit. In order to avoid unnecessary errors caused by inconsistency, a global service is applied in both simulation and reconstruction to ensure that the materials and shapes added in different steps are completely consistent. By specifying different parameters and decay cards, data of different particles, thickness, momentum and direction can be obtained,. Therefore, the dependence of variables we care about how to relay on momentum and angle can be studied.

### Study of single proton and pion

[模拟参数、数据量]

The first step is to study the effect of additional CsI on tag particles. While the physical process Jpsi->p+pi-nbar is selected, the tag particles therefore are p+ and pi-. Compared to pi-, p+ in the same substance will produce larger de/dx, thus at low momentum the efficiency of p+ is much lower than pi-. For this reason, different momentum range is set for p+ and pi-. The minimum momentum is 0.3GeV for p+ and 0.1GeV for pi-, meanwhile, the maximum momentum is 1.2GeV for both p+ and pi-. As for angle, the range of cosine theta is set to [0, 0.93] to ensure the cover of detector. Both momentum and cosine theta obey uniform distribution.

[模拟结果]

[结果讨论]

### Study of single anti-neutron particle

[模拟参数、数据量]

The most direct way to obtain the number of antineutron and CsI interactions is to simulate a single anti-neutron. The range of momentum is set to [0, 1.2] GeV while cosine theta is the same as p+ and pi-. We are interested in the ratio of annihilation and elastic scattering of antineutrons in CsI. For annihilation, the final position of anti-neutron’s track indicates where the annihilation happened, it can be obtained easily with the Mont Carlo truth information. And for elastic scattering, the difference between initial momentum and out-of-CsI momentum shows if the elastic scattering happened or not. The threshold of momentum change is set to 0.01 because if there is no scattering, the momentum change must be strictly equal to 0.

[模拟结果]

[结果讨论]

### Study of jpsi->p+pi-nbar

[模拟参数、数据量]

[模拟结果]

[结果讨论]

## Conclusion and discussion

[cos\_theta增大时，分辨下降，实际实验时可以对不同cos\_theta放置不同厚度的物质]

[放入物质越多，反中子事例越多，但分辨会下降，可以用不同的放置方式平衡数量与质量的关系]

## Acknowledgments