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Research Statement

"*What I cannot create, I do not understand.*"

— Richard Philip Feynman

Just as Feynman's words suggest, the one true way to explore the bounderies of truth is to examine itself with our own "eyes". Every child has been fascinated by the marvelous properties exhibited by elementary particles, and I am no exception. Observing phenomena, establishing theories, and conducting experiments. This is the standard process upon which modern physics is built, and it reflects the logic and philosophy I have adhered to during my undergraduate studies. My engagement in the study and research of QCD phenomenology, collider experiments, and cosmic rays corresponds precisely to these steps. The emergence of new physics at high-energy scales and the appearance of anomalous high-energy particles in the cosmos serve as reminders that we must continuously repeat the process of creating and understanding. This is also the question to which I hope to dedicate my entire life.

Previous Research Experience

• **Solving the gap equation of the NJL model through iterations: unexpected chaos.**

This was my first project, obtained from Prof. Lei Chang, my supervisor. It was during my sophomore year, and Prof. Chang assigned me a simple task as an introduction.

The main objective of this work was to replicate the results of the paper [1]. In this work, we explore the behavior of the iterative procedure to obtain the solution to the gap equation of the NLJ model for arbitrarily large values of the coupling constant. The behavior of the iterative procedure varies depending on the regularization scheme utilized. When employing a hard cut-off, it remains stable and highly accurate. However, with the Paul-Villars and proper time regularization schemes, there emerges a specific coupling constant threshold (distinct for each scheme) beyond which the procedure becomes chaotic and fails to converge.

Although it was not a situation that would happen in real physics, it still provided a good beginning to my research career.

• **Research about contour deformation for computing light-front quantities.**

This was my second project following the paper [2]. It explore a novel approach based on contour deformations and analytic continuation methods to project the Bethe-Salpeter wave function onto the light front. We apply this method to a scalar model and successfully solve the Bethe-Salpeter equation, achieving excellent agreement with the light-front wave functions obtained using the Nakanishi method. We put emphasis on the calculation of the generalization to unequal masses in the Bethe-Salpeter equation and the other is the implementation of complex conjugate propagator singularities. The method is good at handling complex singularities in the integrands. And can be extended to the calculation of parton distributions.

- **Extrapolate lattice pion DA and test its effect on the $\pi - \gamma$ transition form factor.**

This work was inspired by the lattice QCD outcome [3]. And this was my first original project, which resulted in a paper (awaiting submission).

In this study, we present a self-consistent model for the pion's Bethe-Salpeter amplitude (BSA) and quark propagator based on the Schwinger-Dyson and Bethe-Salpeter equations. We compute the pion to two-photons transition form factor, $G^{\gamma^*\pi^0\gamma}(Q^2)$, across a broad range of photon momentum transfer squared. Our model incorporates a dressed quark propagator with complex conjugate pole singularities, indicative of confinement, and a BSA expressed through a spectral density function constrained by modern lattice data. We also include the quark anomalous magnetic moment (AMM) in the quark-photon vertex, which is crucial for the chiral anomaly. Our results for the form factor are consistent with QCD-based predictions and experimental data, slightly exceeding the conformal limit at large Q^2. The associated interaction radius and neutral pion decay width are found to be in agreement with experimental measurements.

- **SoftDrop isolation on exploring QED splitting function.**

After several projects about QCD supervised by Prof. Chang at Nankai University, I decided to do something about collider experiment. I contacted the CMS group in Sapienza University of Rome and finished a fundemental study on photon isolation supervised be Prof. Leticia Cunqueiro. I also wrote a manuscript.

The work was inspired by the paper [4]. The QED splitting function gives the probability density for a quark to emit a photon with a certain fraction of its energy. The quark can lose energy by emitting a photon, and the splitting function characterizes the likelihood of this energy loss. The form of the QED splitting function depends on the specific process under consideration and is derived using perturbation theory. QED splitting function plays an important role in high energy experiments thus we put a great emphasis on it. In this study, we use soft drop isolation to explore the QED splitting function in $q \to q\gamma$ process.

- **From multi-wavelength data to electron distribution.**

The Large Hadron Collider (LHC) at CERN is the most powerful collider ever built by humans on the planet. However, compared to the energy of cosmic rays, which can reach energy scales up to PeV from sources like the Crab Nebula, our means of acceleration are still far from sufficient. The universe itself is a vast accelerator; all we need to do is prepare to receive high-energy guests from distant stars. This is why I went to the Tsung-Dao Lee Institute, Shanghai Jiao Tong University, to study cosmic rays under the guidance of Prof. Gwenael Giacinti.

In this work we claculated the data from Large High Altitude Air Shower Observatory (LHAASO) with Naima package [5] and generated the photon spectrum we got from the Crab Nebula and analyzed the origin of these photons. In this study we considered the distribution of inverse compton, Cosmic Microwave Background (CMB), self synchrotron compton, pion decay, exponential cutoff broken power law and exponential cutoff double broken power law.

Ongoing and Upcoming Research

- **Calculation of Various Form Factors with a Novel Approach.**

  Inspired by the paper [6], we are trying to calculate the various form factors of pion under the ladder approximation of the Bethe-Salpeter equation, with contact interactions. The work is supervised by Prof. Chang.

- **ttH+tH CP analysis on ATLAS.**

  We will train a neural network to separate ttH+tH signal from background processes and to separate events produced by CP-even and CP-odd process simultaneously. The work will be supervised by Prof. Caterina Vernieri and Dr. Brendon Bullard at SLAC.

References

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