【Grant-in-Aid for Scientific Research (S)】

Broad Section B

Title of Project： Gluon saturation and origin of QGP probed by forward photons at LHC

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Keyword：Color Glass Condensate, QGP, ALICE experiment, LHC accelerator, Silicon electromagnetic calorimeter

【Purpose and Background of the Research】

There is an undiscovered state in quantum chromodynamics (QCD) that describes the "strong force" acting on elementary particles. That is a "Color Glass Condensate (CGC)". This state is a high-density gluon matter predicted by QCD, and at the same time gives an initial condition of Quark Gluon Plasma (QGP) that appears in high-energy heavy ion collisions. Therefore, CGC is linked to our fundamental understanding of "strong force". Many experimental studies have been carried out so far, but no clear signal has been obtained. We have developed a highly segmented silicon electromagnetic calorimeter detector "FoCal" that can capture clear signal of CGC under high particle density.

In this study, a part of FoCal will be constructed and installed prior to the LHC-ALICE experiment, and the existence of CGC will be experimentally explored by detecting decay photons from neutral mesons by FoCal and the existing ALICE detector. We will elucidate the origin of QGP formation and the mechanism of early thermalization that appear in heavy ion reactions. This is a new international collaboration led by the Japanese team.

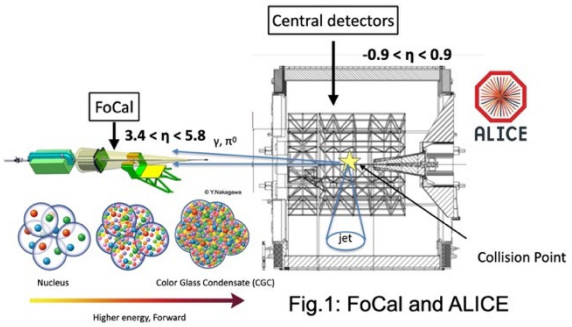

Fig.1: FoCal and ALICE

【Research Methods】

To obtain a clear signal of CGC, the following three points are important; (1) Measurement in the very forward direction (beam axis, zero degrees direction), (2) Use of high energy heavy ion beams, (3) Identification of probes sensitive to gluon density. Therefore, we use the accelerator LHC (Large Hadron Collider, CERN (Switzerland)), which provides the world's highest energy lead nucleus beams, and install FoCal in the very forward direction of the ALICE experiment to probe the gluon density of lead nucleus. This is the first time in the world to detect a photon in the very forward direction, which is a sensitive to the gluon density.

Japanese team will lead the project to produce the "FoCal-E PAD" detector, which is the main part of energy measurement in FoCal. Furthermore, in 2024 during the LHC Run-3, a part of the assembled FoCal module will be installed prior to the ALICE experiment, and initial physics measurement and the fist data analysis will be performed.

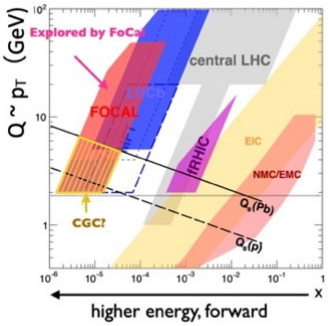

Fig. 2: New regime explored by FoCal

【Expected Research Achievements and Scientific Significance】

Using the FoCal, the following points will be clarified by the π^0 mesons and their correlation measurements. (1) Where does the saturation of gluon density appear (discovery of Color Glass Condensed), (2) Exploring the ridge structure that appears in a small collision system with a wider $\Delta\eta$ region (origin of QGP, early thermalization), (3) World's first measurement of jet suppression and QGP fluid development in the very forward region ($3.5 < \eta < 4.5$) in Pb-Pb collisions.

These findings will clarify the entire QGP creation mechanism in heavy ion collisions, and new developments in quantum chromodynamic phase diagram are expected. On the technical side, there are potential for new medical applications such as proton CT by FoCal.

【Publications Relevant to the Project】

- Letter of Intent: A Forward Calorimeter (FoCal) in the ALICE experiment, ALICE Collaboration (T. Chujo et al.), CERN-LHCC-2020-009, LHCC-I-036, ALICE-PUBLIC-2019-005.
- S. Acharya, T. Chujo et al., ALICE Collaboration, "Measurement of charged jet cross section in pp collisions at $\sqrt{s}$ =5.02 TeV", Phys. Rev. D 100 (2019), 092004.

【Term of Project】 FY2020-2024

【Budget Allocation】 149,800 Thousand Yen

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