【Grant-in-Aid for Specially Promoted Research】

ALICE FoCal experiment - exploring QGP creation from initial stages

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Project Information	Project Number : 24H00003　Project Period (FY) : 2024-2030 Keywords : High energy heavy ion collisions, Quark Gluon Plasma, Color Glass Condensate, Early universe, LHC accelerator

Purpose and Background of the Research

●Outline of the Research

According to the Big Bang theory, the early universe, several tens of microseconds after the creation of the universe, was at an extremely high temperature of several trillion K or more. It is considered a soup of elementary particles called ”Quark-Gluon Plasma (QGP)". Since the 2000s, we contributed to the discovery of QGP and determination of QGP properties. However, there are still unanswered key questions; 1) how QGP is created and 2) what is the initial condition of QGP formation, namely does a color glass condensate (CGC), undiscovered high-density gluon matter exist? And what is the nature of CGC?

To answer these questions, we organized the "FoCal Japan" consisting of 11 institutions. We will construct a new detector system in a forward direction at the LHC "FoCal”. FoCal is the world's first detector that can measure direct photons, at the extremely small x regions, down to 1/1000 of the conventional parton momentum fraction (x) and can directly measure various probes. In this region, CGC is expected to appear, which holds the key to solving the formation mechanism of QGP. FoCal will be able to capture CGC signals with an unprecedent precision. Japanese experimental and theoretical researchers in this proposal will work together to answer those key questions above.

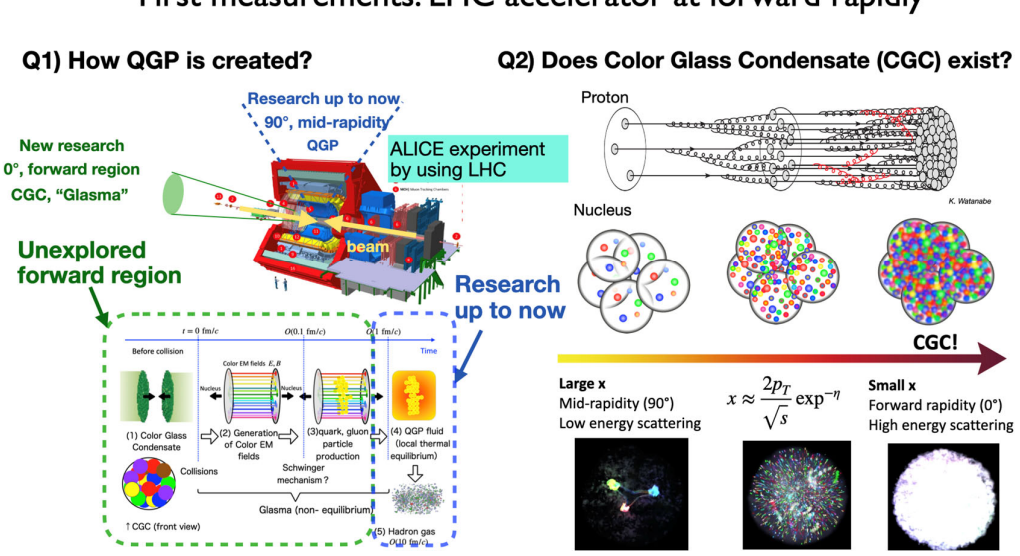

Figure 1. Overall image of this research

●Uniqueness of research

There are two unique points.

1) LHC forward: To measure the evidence and evolution of CGC for the first time in by using the energy frontier accelerator; LHC at CERN and at the forward direction

2) New technology: Capability of direc photons measurement by separating two photons in the distance of ~1 mm scale for the first time

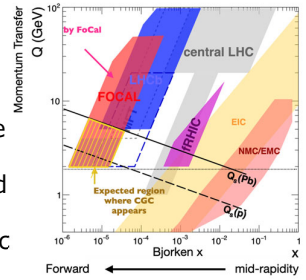

Figure 2. Expected region of CGC

Figure 3. A prototype of FoCal detector (KAKENHI, Kiban (S) 20H05638)

Regarding 1), whereas conventional measurements is limited to the region of x = 10^{-2} to 10^{-3}, by covering a LHC forward region, it becomes possible for the first time in the world to measure the region of x = 10^{-6}, where the effect of CGC is expected to be noticeable. Furthermore, the unique technology described in 2) will make it possible for the first time to capture a clear CGC probe.

Expected Research Achievements

●Research Plan

The goals of this research are (1) measurement of the gluon density in a nucleus, (2) discovery and evolution of CGC, and (3) elucidation of the QGP formation mechanism and early thermalization mechanism. Therefore, we will conduct the following researches. (I) The FoCal detector will be constructed, installed and operated lead by FoCal Japan group, (II) Physics data taking and data analysis in 2029-2032 and publishing the results, (III) Organizing a theoretical research team, and study CGC, strong color electromagnetic field, early thermalization, and Glasma/QGP fluid creations.

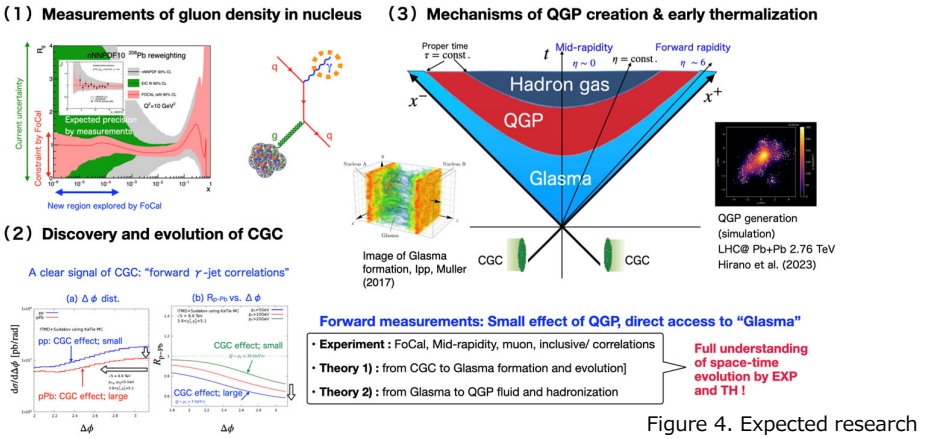

Figure 4. Expected research achievements by FoCal

●Academic significance, social implementation

Observing CGC is a direct look at the most distinctive properties of the fundamental theory of strong force, quantum chromodynamics (QCD). This research also deals with strong color fields. Among them, understanding the instantaneous production of quarks by the Schwinger mechanism and the mechanism of early thermalization holds the key to QGP creation. In addition, FoCal technology can be used for "proton CT," a cancer diagnosis and treatment tool and a future detector at the EIC in the USA.

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