論文の内容の要旨

J/ψ production in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV
(核子あたり重心系衝突エネルギー 5.02 TeV での陽子鉛衝突における J/ψ 生成)

氏 名　　林 真一

Quantum Chromodynamics predicts quark deconfinement and the transition to strongly interacting matter, quark-gluon plasma (QGP), at extremely high temperature and density. Relativistic heavy ion collisions are an unique tool to study the properties of QGP. Since the yield of J/ψ is expected to decrease in QGP due to Debye screening of color charges, J/ψ suppression is one of the strong signatures of QGP formation [1]. PHENIX experiment at the Relativistic Heavy Ion Collider (RHIC) in the Brookhaven National Laboratory (BNL) observed strong suppression of J/ψ production in Au–Au collisions at $\sqrt{s_{NN}} = 200$ GeV [2]. The J/ψ yields measured by the ALICE experiment at the Large Hadron Collider (LHC) in the European Organization for Nuclear Research (CERN) were also suppressed in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV. In addition, non-negligible suppression of the J/ψ yield was observed in d–Au collisions at $\sqrt{s_{NN}} = 200$ GeV at RHIC. Suppression in d–Au collisions is thought as normal nuclear matter effects such as gluon shadowing and nuclear absorption. The understanding of normal nuclear matter effects in heavy ion collisions is essential in the discussion of the QGP effects.

This thesis presents the measurement of inclusive J/ψ production in minimum bias p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV at mid-rapidity ($-1.37 < y < 0.43$) with the ALICE central barrel detectors. The main aim of this analysis is the investigation of normal nuclear matter effects in relativistic heavy ion collisions. J/ψ is detected via dielectron decay channels by calculating their invariant mass. In the ALICE central barrel, electrons are reconstructed using the Inner Tracking System (ITS) and the Time Projection Chamber (TPC) in $|\eta| < 0.9$. Figure 1 shows the p_{T}-integrated invariant mass spectra of unlike-sign, expected background, and background subtracted pairs. Since the main source of the background is combinatorial pairs, event mixing technique is used to estimate the shapes of the background.

The measured production cross section of inclusive J/ψ in p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV at mid-rapidity ($-1.37 < y < 0.43$) is determined by

$$\frac{d\sigma_{J/\psi}}{dy} = 930 \ \pm \ 83 \text{ (stat)} \ \pm 74 \text{ (syst) } \mu\text{b}. \tag{1}$$

In order to investigate nuclear matter effects in p-Pb collisions, the nuclear modification factor (R_{pPb}) is introduced. It is defined as

$$R_{\mathrm{pPb}} = \frac{Y_{\mathrm{pPb}}}{\langle N_{coll}\rangle Y_{\mathrm{pp}}}, \tag{2}$$

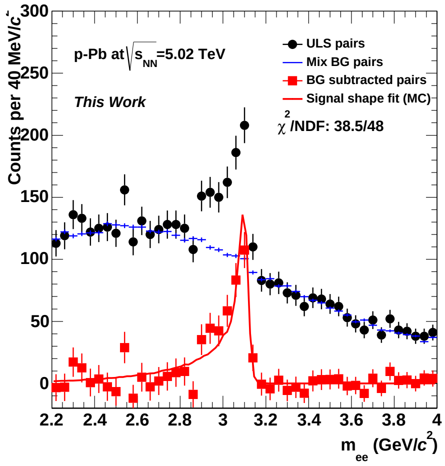

Fig.1 Invariant mass distribution of unlike-sign, mixing background, and background subtracted pairs in p-Pb collisions. The solid red line shows the result of the fitting to the subtracted signal.

where $Y_{\rm pPb}$, $Y_{\rm pp}$ are the invariant yield of J/ψ in pp and p–Pb collisions, respectively. $\langle N_{coll}\rangle$ is the average number of binary nucleon-nucleon collisions in p–Pb collisions. In this analysis, the J/ψ yield in pp collisions at $\sqrt{s} = 5.02$ TeV is estimated by interpolation from the measured pp spectra [6]. $R_{\rm pPb}$ of inclusive J/ψ production at mid-rapidity (-1.37 $< y <$ 0.43) is extracted as

$$R_{\rm pPb} = 0.74\ \pm\ 0.07\ ({\rm stat})\ \pm\ 0.13\ ({\rm syst}). \tag{3}$$

Compared with $R_{\rm pPb}$ at forward rapidity via the dimuon decay measurements, the magnitude of $R_{\rm pPb}$ at mid-rapidity is compatible within the uncertainties.

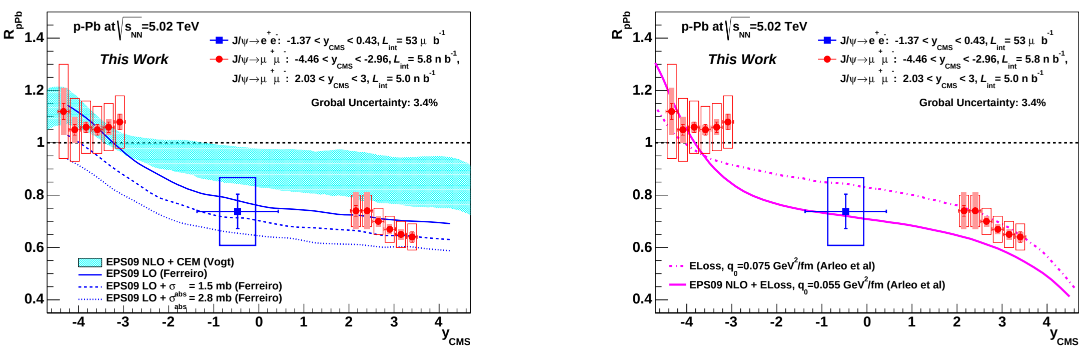

Fig.2 Comparison of the rapidity y dependence of the data to the gluon shadowing models (Left) and the coherent energy loss model (Right) in p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV [8, 9].

The left panel of Fig. 2 shows the comparison of the y dependence of $R_{\rm pPb}$ with the shadowing model calculations [8–10]. At mid-rapidity, both EPS09 NLO and LO calculations are consistent with the experimental results within the uncertainties. The right panel of Fig. 2 shows the comparison of the y dependence of $R_{\rm pPb}$ with the coherent energy loss model calculation [10]. Coherent energy loss model with typical transport coefficient $\hat{q}$ shows a reasonable description of the y dependence of the measured

$R_{\rm pPb}$. Figure 3 shows the comparison of the $p_{\rm T}$ dependence between the measured $R_{\rm pPb}$ and the model calculations [10, 11]. The coherent energy loss model shows the reasonable description of both y and $p_{\rm T}$ dependence of the data. However, the uncertainties of data and model calculations are still large. The further reduction of the uncertainties is needed to obtain the conclusive explanation of normal nuclear matter effects in heavy ion collisions at LHC.

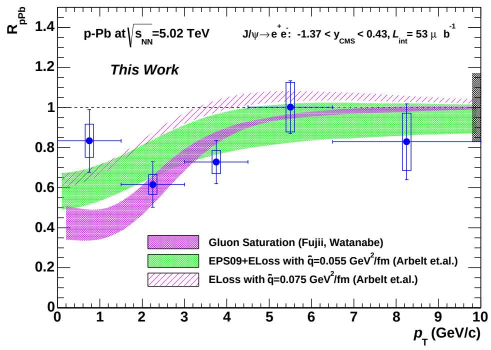

Fig.3 Comparison of the $p_{\rm T}$ dependence between the measured $R_{\rm pPb}$ and the model calculations in p–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV. The violet, green, and magenta bands show the calculation based on gluon saturation with CGC framework, coherent energy loss with EPS09 nPDF parametrization, and coherent energy loss with the proton PDF parametrization [10, 11].

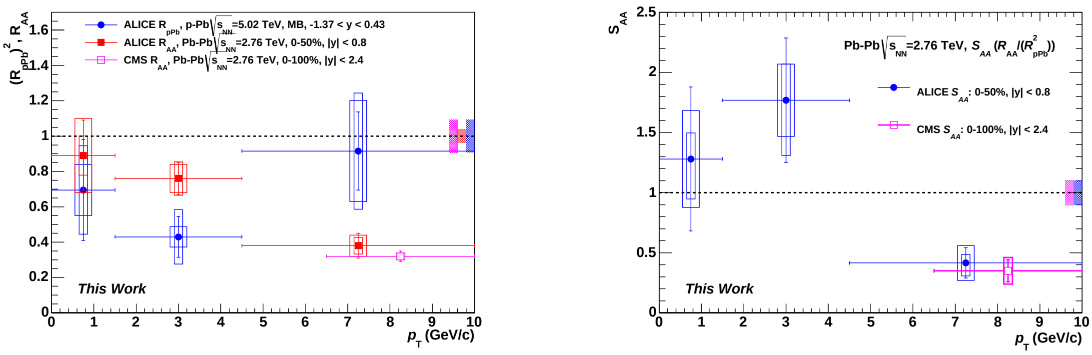

Fig.4 Comparison of R_{AA} and $(R_{\rm pPb})^2$ in ALICE and CMS (Left) and surviving fraction (S_{AA}) (Right) of J/ψ production in Pb–Pb collision.

Under the assumption that the shadowing effect is dominant compared to other normal nuclear matter effects, normal nuclear matter effects in R_{AA} is approximated by the convolution of $R_{\rm pPb}$ [7]. Figure 4 shows the inclusive J/ψ R_{AA} in Pb-Pb collisions at $\sqrt{s_{NN}}$ =2.76 TeV in 0–50% centrality and the product of inclusive J/ψ $R_{\rm pPb}$ and surviving fraction (S_{AA}) defined as

$$S_{AA} = \frac{R_{AA}}{R_{\rm pA}(-y) \times R_{\rm pA}(y)}. \tag{4}$$

Compared between $(R_{\rm pPb})^2$ at $\sqrt{s_{NN}} = 5.02$ TeV and $R_{\rm AA}$ in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV, the suppression is seen at high p_T above 4.5 GeV/c. This suppression is qualitatively consistent with the color screening pictures. On the other hand, the enhancement of the J/ψ yield is observed at lower p_{T}, which is due to the regeneration of J/ψ in Pb–Pb collisions [12].

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