

CNS Annual Report 2022

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Book of Abstracts

Contents

| | |
|--|---|
| New implantation detectors for decay spectroscopy at fragmentation facilities | 1 |
| Improved ${}^6\text{He}$ beam production at CRIB with MWDC and degraders | 1 |
| Multiplicity dependence of direct photon production in pp collisions at $\sqrt{s} = 13$ TeV . . | 1 |
| Data analysis of OEDO day 0 experiment measuring ${}^{93}\text{Zr} + \text{d}$ transmutation reactions for the study of deuteron breakup | 2 |
| Direct measurement of the ${}^{26}\text{Si}(\alpha, \text{p}){}^{29}\text{P}$ reaction at CRIB for the nucleosynthesis in the X-ray bursts | 3 |
| Development of sustainable ${}^{24}\text{Mg}^{8+}$ beam production at HyperECR | 3 |
| Report on OEDO-SHARAQ experiments in FY2022 | 4 |
| Optical system for the optical lattice trapping of heavy alkali atoms | 4 |
| Direct mass measurement of proton-rich Fe isotopes | 5 |
| surrogate reaction of ${}^{130}\text{Sn}(\text{n}, \text{g})$ at OEDO | 5 |
| Measurement of fusion-evaporation cross sections in ${}^{136}\text{Xe} + {}^{64}\text{Zn}$ system using inverse kinematics | 5 |
| Development and commissioning of a mosaic type array formed by Si photodiodes . . . | 6 |
| Current status of the development of the emittance monitor for high-intensity ion beams accelerated by AVF Cyclotron | 6 |
| Recent activities on an active target CAT-M | 7 |
| Preliminary results on the reaction of the ${}^6\text{He} + \text{p}$ scattering experiment in MS | 7 |
| Dielectron production in central PbPb collisions at $\sqrt{s_{\text{NN}}} = 5.02$ TeV | 7 |
| Gamma ray measurement with position-sensitive Ge detector array GRAPE using the ${}^{238}\text{U}$ beam at the RI Beam Factory | 8 |
| Study of dielectron measurement capabilities in the phase 3 upgrade of the LHC-ALICE experiment | 8 |
| Study of space-charge distortion correction for the ALICE Time Projection Chamber using machine learning techniques | 8 |

| | |
|---|----|
| Measurement of long-range two-particle correlation and $v_2(\eta)$ in p-Pb collisions at 5.02 TeV | 9 |
| Development of a Radio Frequency Dipole Mass Filter for the Francium Permanent Electric Dipole Moment Search | 9 |
| Half-life measurement of 107-keV isomeric state in ^{45}Cr | 9 |
| Direct measurement of the $^{14}\text{O}(\alpha,p)^{17}\text{F}$ reaction with the Texas Active Target v2 detector | 10 |
| Measurement of double charge exchange ($^{12}\text{C}, ^{12}\text{Be}(0_2^+)$) reaction aiming for the observation of double Gamow-Teller giant resonance | 10 |
| Isomeric gamma ray measurement system at S2+ in SHARAQ13 experiment | 11 |
| Charge exchange reaction of rubidium and francium ions using an yttrium neutralizer | 11 |
| Study of νp process nucleosynthesis at OEDO | 11 |
| Cathode-readout self-triggering system on a multi wire drift chamber | 12 |
| Spectroscopy of ^{32}Mg via one-neutron and two-proton knockout reactions | 12 |
| TBA | 12 |

1

New implantation detectors for decay spectroscopy at fragmentation facilities

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The study of β decays far from stability is essential to understand the evolution of nuclear structure and nucleosynthesis processes. β decay experiments with such exotic nuclei involve intense cocktail beams from fragmentation facilities. The role of an implantation detector in these experiments is to measure the energy and the positions of both heavy ion implantation and β ray emission to correlate the identified ion with β decay events.

Due to the lack of time resolution of conventional Silicon strip detectors, we have developed a new implantation detector using a segmented YSO (Yttrium Orthosilicate) scintillator array for time of flight spectroscopy of the β delayed neutron emission. The new detector was implemented in β delayed neutron measurement experiments at RIKEN RI Beam Factory, and it was confirmed that the YSO detector correlates β and implant events better due to its higher effective atomic number $Z \sim 35$.

The success of the YSO detector motivated us to develop a new detector using heavier scintillator material. We will report on the design of the new detector using (Gd,139La)₂Si₂O₇:Ce (A=139 enriched La GPS) crystal which has a much higher effective atomic number ($Z \sim 51$) and is expected to have better β implant efficiency with a lower background.

2

Improved ^6He beam production at CRIB with MWDC and degraders

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The second ^6He beam production test at CRIB was carried out in Oct. 2022 as a two-day Machine Study (MS-EXP22-05), to improve the effective intensity and purity of the ^6He beam by introducing wire chambers (MWDC) and degraders. We report the result of the test, presenting the comparison of beam parameters with the previous test.

3

Multiplicity dependence of direct photon production in pp collisions at $\sqrt{s} = 13 \text{ TeV}$

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In this report, we report multiplicity dependence of direct photon production in pp collisions at $\sqrt{s} = 13$ TeV. The purpose of this study is to investigate if thermalized system such as the quark-gluon plasma (QGP) is created even in the small colliding system.

4

Data analysis of OEDO day 0 experiment measuring $^{93}\text{Zr} + d$ transmutation reactions for the study of deuteron breakup

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In Autumn 2017, the OEDO setup was commissioned during a series of day 0 experiments performed by the ImPACT 17-02-01 collaboration. One of these experiments measured $^{93}\text{Zr}+d$ transmutation reactions at ~ 28 MeV/u, the lowest energy to date. Deuterons have a low binding energy (2.224 MeV) and therefore undergo breakup whilst in the presence of Coulomb and nuclear fields. By comparing measured cross-sections of the $^{93}\text{Zr}+d$ reactions with theoretical calculations, the role of deuteron breakup on the production cross-sections may be better understood. During 2022 data analysis

of the $^{93}\text{Zr}+d$ measurement has been performed and cross sections extracted. Comparisons with theoretical calculations such as DEURACs are now underway. We report the status of the analysis and results.

5

Direct measurement of the $^{26}\text{Si}(\alpha, p)^{29}\text{P}$ reaction at CRIB for the nucleosynthesis in the X-ray bursts

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In the X-ray bursts, the $^{26}\text{Si}(\alpha, p)^{29}\text{P}$ reaction rate has a great impact on the light curve. However, there was not enough experimental data for this reaction because of the technical difficulty.

A direct measurement was performed at the CNS RI beam separator (CRIB). And the yield of the (α, p) reaction was determined by removing the background events seen in the measurements. Due to the large number of background events and the large statistical error, an upper bound for the reaction cross section was obtained, which was 0.134 times the NON-SMOKER statistical model.

The analysis method and the results will be discussed.

6

Development of sustainable $^{24}\text{Mg}^{8+}$ beam production at Hyper-ECR

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In collaboration with the CRIB spectrometer group, we have been developing a magnesium beam that can be provided for long-term experiments. CNS 14 GHz HyperECR ion source provides various metal ion beams to the RIKEN AVF cyclotron. The magnesium beam was already been put to practical use, however, its intensity and sustainability had not met the requirements of the experiment group. Therefore, developments in beam production have been put forward. This report discusses two methods for $^{24}\text{Mg}^{8+}$ beam production.

7

Report on OEDO-SHARAQ experiments in FY2022

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We briefly report the OEDO-SHARAQ experiments performed in FY2022.

8

Optical system for the optical lattice trapping of heavy alkali atoms

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Precision spectroscopy of heavy atoms, including francium, is expected to provide insight into the origins of fundamental symmetry violation. The key for achieving high experimental sensitivity is to cool the atoms and trap them within the measurement region. We report on the construction of an optical system that enables us to trap alkali atoms in a one-dimensional optical lattice. The system is built to work with a laser-cooled ensemble of stable rubidium or cesium atoms, but also serves as a prototype for francium atoms.

10

Direct mass measurement of proton-rich Fe isotopes

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The two-proton radioactivity (2p decay) is an exotic decay mode that was predicted theoretically in the 1960s and first discovered experimentally in 2002. Two protons are simultaneously emitted from the ground state of some neutron-deficient nuclei such as ¹⁹Mg, ⁴⁵Fe, ⁴⁸Ni, and ⁵⁴Zn.

Because the two-proton emitters are very undatable, it is difficult to study their energy structure, and the mechanism of 2p decay is not fully established.

In this research, we performed the direct mass measurement of ⁴⁵Fe and the nucleus in its vicinity to reveal the energy structure and proton separation energy using the Tof-Brho method in the OEDO-SHARAQ beamline. We are aiming to evaluate the probability that two protons tunnel the potential barrier. The present status of the data analysis will be reported.

11

surrogate reaction of ¹³⁰Sn(n,g) at OEDO

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¹³⁰Sn(d,p) reaction in the inverse kinematics was measured at OEDO/SHARAQ beam line to deduce the neutron capture reaction rate of ¹³⁰Sn. The energy degraded ¹³⁰Sn, ¹³⁰Te, and ¹²⁴Sn beams were directed onto a thin CD2 target. The reaction residues were identified by the SHARAQ in coincidence with the recoiled protons detected by TiNA2 array.

12

Measurement of fusion-evaporation cross sections in ¹³⁶Xe+⁶⁴Zn system using inverse kinematics

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The heavy-ion fusion reaction is powerful in expanding the chart of nuclides as well as exploring the nuclear structure beyond Pb ($Z = 82$). A fusion experiment was performed at HIMAC to study the inverse kinematic systems by bombarding the low-energy ^{136}Xe beam onto ^{27}Al , ^{nat}Cu and ^{nat}Zn targets. Two newly developed detectors were used in the experiment: a position-sensitive mosaic detector array which is composed of 128 Silicon photodiodes for the in-beam α measurement and a ToF spectrometer based on the Micro Channel Plates to measure the beam energy, respectively. Partial Fusion-Evaporation Residues were identified by measuring the decayed α particles and β -delayed γ rays, independently. The excitation functions of partial ERs were deduced and compared with the calculations using statistical models.

13

Development and commissioning of a mosaic type array formed by Si photodiodes

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Si detectors are extensively applied in the measurement of charged particles produced in fusion reactions. In order to achieve a relatively low-cost charged-particle detection with fair position sensitivity, we have developed a mosaic-type detector array based on Si photodiodes (Hamamatsu S13955-01). Its high modularity allows one to modify the geometric configuration of the array according to specific experimental requirements. The detector array was commissioned using $^{136}\text{Xe} + ^{nat}\text{Zn}$ reaction in July 2022 at HIMAC. In this report, details of the detector development and experimental results are presented.

14

Current status of the development of the emittance monitor for high-intensity ion beams accelerated by AVF Cyclotron

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We will report the current status of the development of emittance monitor for high-intensity beam accelerated by AVF Cyclotron.

15

Recent activities on an active target CAT-M

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An active target CAT-M has been developed to perform traditional reactions with light ions in inverse kinematics. Recently we installed a dipole magnetic field using permanent magnets to improve the signal-to-noise ratio by confining delta-electrons within the beam region. TTT silicon detectors from KU Leuven were employed for a better angular resolution in laboratory frame and resulting better excitation energy resolutions. In this paper, the recent development and series of experiments will be introduced.

16

Preliminary results on the reaction of the ${}^6\text{He}+p$ scattering experiment in MS

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The Machine study for the ${}^6\text{He}+p$ experiment was carried out in CRIB, the ${}^6\text{He}$ beam energy was ~ 48 MeV with 91% purity via 20 μm mylar degrader. We also carried out one short scattering measurement of the ${}^6\text{He}+p$ reaction with one set of dE-E detectors, the locus of the p, d, t, alpha, ${}^6\text{He}$ can be clearly seen. The proton and triton were identified combined with the kinematic calculation of the ${}^6\text{He}(p,p){}^6\text{He}$ and ${}^6\text{He}(p,t){}^4\text{He}$ reactions. In addition, the cross section of the ${}^6\text{He}(p,p){}^6\text{He}$ and ${}^6\text{He}(p,t){}^4\text{He}$ reaction were roughly calculated, which is consistent with the tendency of the theoretical calculation.

17

Dielectron production in central PbPb collisions at $\sqrt{s_{\text{NN}}} = 5.02$ TeV

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The Dielectron production in central PbPb collisions at $\sqrt{s_{\text{NN}}} = 5.02$ TeV is discussed.

18

Gamma ray measurement with position-sensitive Ge detector array GRAPE using the ^{238}U beam at the RI Beam Factory

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Gamma-Ray Detector Array with Position and Energy Sensitivity (GRAPE) has been developed since 2000 for high-resolution in-beam γ -ray spectroscopy using Radioactive Ion (RI) beams.

In the RIBF DA21-05 machine time, ^{238}U at 650 keps intensity and 307 MeV/u energy irradiated TiD, Ti, and CD2 targets, and gamma rays emitted at the F8 focal plane were measured with 6 GRAPE detectors. Background events were removed using a Si detector surrounding the F8 target. The measured gamma-ray spectra are described.

19

Study of dielectron measurement capabilities in the phase 3 upgrade of the LHC-ALICE experiment

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In this report, we report dielectron measurement capabilities in the phase 3 upgrade of the LHC-ALICE experiment.

The purpose of this study is to evaluate whether the electrons from the pre-equilibrium process can be measured using electron identification by ECal.

21

Study of space-charge distortion correction for the ALICE Time Projection Chamber using machine learning techniques

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The current status of studies on the ALICE-TPC space-charge distortion correction using machine learning methods will be discussed in this article.

22

Measurement of long-range two-particle correlation and $v_{\{2\}}(\eta)$ in p-Pb collisions at 5.02 TeV

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TBA

23

Development of a Radio Frequency Dipole Mass Filter for the Francium Permanent Electric Dipole Moment Search

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In order to improve the measurement accuracy of the permanent electric dipole moment of francium (Fr), a radio frequency dipole mass filter (RFD MF) was developed to improve the purity of Fr ion beam. RFD MF has the unique feature of enabling mass separation in the very short beam transport system of only a few tens of centimeters. The experiment to evaluate its performance with Fr ion beam showed that the Fr ion beam purity was increased by a factor of 2.9.

24

Half-life measurement of 107-keV isomeric state in ⁴⁵Cr

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We did the experiment that carried out mass measurements around ⁴⁷Fe in May 2022. Then, we made a lot of unstable nuclei. Some of them emitted γ -rays and backed to ground state. These γ -rays measured by Ge detector. In this experiment, we succeeded in measuring the half-life of the 107-keV isomeric state in ⁴⁵Cr.

Direct measurement of the $^{14}\text{O}(\alpha,p)^{17}\text{F}$ reaction with the Texas Active Target v2 detector

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Recent sensitivity studies showed that the $^{14}\text{O}(\alpha,p)^{17}\text{F}$ is one of the very important reactions affecting a large uncertainty of energy generation and final ash in X-ray burst models. The reaction was also emphasized as a key determination of the break-out path from the hot CNO cycle to the rp -process at sufficiently high temperatures ($T_9 > 0.5$), specifically the spin and parity of a resonance state at $E_x = 6.15$ MeV plays an important role. In order to constrain the astrophysical reaction rate, the total cross section measurement along the large range of E_{cm} is necessary. We performed the direct measurement of the reaction with the Texas Active Target v2 (TexAT_v2) detector to experimentally provide the key information. The ^{14}O beam energy on the target was 3.36 MeV/u, corresponding to $E_{cm} = 10.45$ MeV and the TexAT_v2, which is an active-target time projection chamber enabling reconstructions of particle tracks in the detector, measured the proton tracks from the reaction. A silicon detector array and a CsI(Tl) detector array around the active area provide the total energy deposition of light particles and particle identification if a particle escapes the active TPC volume. The data analysis is in progress and the details of the experiment setup will be explained in the manuscript.

Measurement of double charge exchange ($^{12}\text{C}, ^{12}\text{Be}(0_2^+)$) reaction aiming for the observation of double Gamow-Teller giant resonance

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We performed a missing mass spectroscopy at RIBF using double charge exchange reaction $^{48}\text{Ca}(^{12}\text{C}, ^{12}\text{Be}(0_2^+))$, aiming for the observation of the double Gamow-Teller giant resonance. We observed some structures in the excitation energy spectrum of ^{48}Ti at the energy region where the double Gamow-Teller giant resonance is expected to exist. We compared the experimental angular distribution to the theoretical calculation. The present status of the analysis will be reported.

27

Isomeric gamma ray measurement system at S2+ in SHARAQ13 experiment

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In the SHARAQ13 experiment, mass measurement of the proton-rich isotopes around ^{47}Fe has been performed. To assist the particle identification and to search for new isomeric states, the gamma-ray detectors for the isomer tagging were installed in the air downstream of the final focal plane(S2). Two HPGe detectors were placed perpendicular from the beam direction. To confirm the accuracy of isomer energy and half-life determination, the known isomers ^{38}K , ^{43}Sc , ^{46}Sc , ^{43}Ti , and ^{46}V were analyzed.

28

Charge exchange reaction of rubidium and francium ions using an yttrium neutralizer

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In this report, charge exchange reaction of rubidium and francium ions using an yttrium neutralizer is discussed.

29

Study of νp process nucleosynthesis at OEDO

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30

Cathode-readout self-triggering system on a multi wire drift chamber

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We are developing a single-channel readout from the cathode planes of a multi wire drift chamber to achieve both self triggering and high tracking efficiency in ${}^6\text{He}$ beam experiments at CRIB.

32

Spectroscopy of ${}^{32}\text{Mg}$ via one-neutron and two-proton knockout reactions

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33

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