Elemental abundance anomalies in globular clusters - I

D.P. Carrasco-Rojas,[1] M. Williams,[2, 3] P. Adsley,[4, 5, 6, 7] L. Lamia,[8, 9, 10] B. Bastin,[11] T. Faestermann,[12] C. Fougeres,[11] F. Hammache,[13] D.S. Harrouz,[13] R. Hertenberger,[14] M. La Cognata,[8] A. Meyer,[13] F. de Oliveira Santos,[11] S. Palmerini,[15, 16] R.G. Pizzone,[8] S. Romano,[8] N. de Sereville,[13] A. Tumino,[8, 17] and H.-F. Wirth[14]

[1]*Department of Physics, The University of Texas at El Paso, El Paso, TX 79968-0515, USA*
[2]*TRIUMF, Vancouver, BC V6T 2A3, Canada*
[3]*Department of Physics, University of York, Heslington, York, YO10 5DD, United Kingdom*
[4]*Department of Physics and Astronomy, Texas A&M University, College Station, Texas 77843-4242, USA*
[5]*Cyclotron Institute, Texas A&M University, College Station, Texas 77843-3636, USA*
[6]*iThemba Laboratory for Accelerator Based Sciences, Somerset West 7129, South Africa*
[7]*School of Physics, University of the Witwatersrand, Johannesburg 2050, South Africa*
[8]*Laboratori Nazionali del Sud - Istituto Nazionale di Fisica Nucleare, Via Santa Sofia 62, 95123 Catania, Italy*
[9]*Dipartimento di Fisica e Astronomia "E.Majorana", Universit`a di Catania, Italy*
[10]*Centro Siciliano di Fisica Nucleare e Struttura della Materia (CSFNSM), Catania, Italy*
[11]*GANIL, CEA/DRF-CNRS/IN2P3, Bvd Henri Becquerel, 14076 Caen, France*
[12]*Physik Department E12, Technische Universit¨at M¨unchen, D-85748 Garching, Germany*
[13]*Universit´e Paris-Saclay, CNRS/IN2P3, IJCLab, 91405 Orsay, France*
[14]*Fakult¨at f¨ur Physik, Ludwig-Maximilians-Universit¨at M¨unchen, D-85748 Garching, Germany*
[15]*Dipartimento di Fisica e Geologia, Universit`a degli Studi di Perugia, via A. Pascoli s/n, 06125 Perugia, Italy*
[16]*Istituto Nazionale di Fisica Nucleare - Sezione di Perugia, via A. Pascoli s/n, 06125 Perugia, Italy*
[17]*Facolt`a di Ingegneria e Architettura, Universit`a degli Studi di Enna "Kore", Cittadella Universitaria, 94100 Enna, Italy*

Most globular clusters show anticorrelations between some elemental abundances such as the common sodium-oxygen (NaO) anticorrelation, as well as more unusual cases such as magnesium-potassium (MgK) anticorrelations. These abundance anomalies cannot have been caused by the current generation of stars within globular clusters, but must have resulted from some previous stars. The nature of these stars is unclear due to uncertainties in the nuclear reaction rates controlling the creation and destruction of the elements seen in the abundance anomalies.

There are a number of important reactions which are being investigated at various laboratories around the world. The ^{22}Ne(p,γ)^{23}Na reaction produces sodium, relevant to the NaO anticorrelation. There are some large uncertainties in this reaction due to unclear spectroscopic information on the compound nucleus, ^{23}Na. There may be additional low-energy resonances which could enhance the reaction rate by a factor of ten. The direct ^{22}Ne(p,γ)^{23}Na measurement is highly challenging due to the low cross section; detailed studies at the Laboratory for Underground Nuclear Astrophysics (LUNA at INFN-Gran Sasso have pushed the limits for these low-lying resonance strengths down to very low levels but the factor ten uncertainty persists. We have used the ^{23}Na(p,p') reaction, which has weak to no selectivity to the structure of the excited states, at the Munich Q3D spectrometer to search for possible resonance states and have concluded that they do not exist, reducing the uncertainty in the reaction rate at temperatures relevant to hot-bottom burning from a factor of ten to around 40%.

These data were analysed by a TREND student, Diana Carrasco-Rojas, and are under review in Phys. Rev. C.

Fig. 1 shows the excitation-energy spectrum of ^{23}Na following the ^{23}Na(p,p') reaction. The green vertical lines show the expected location of the tentative resonance states which have not been observed in the present measurement.

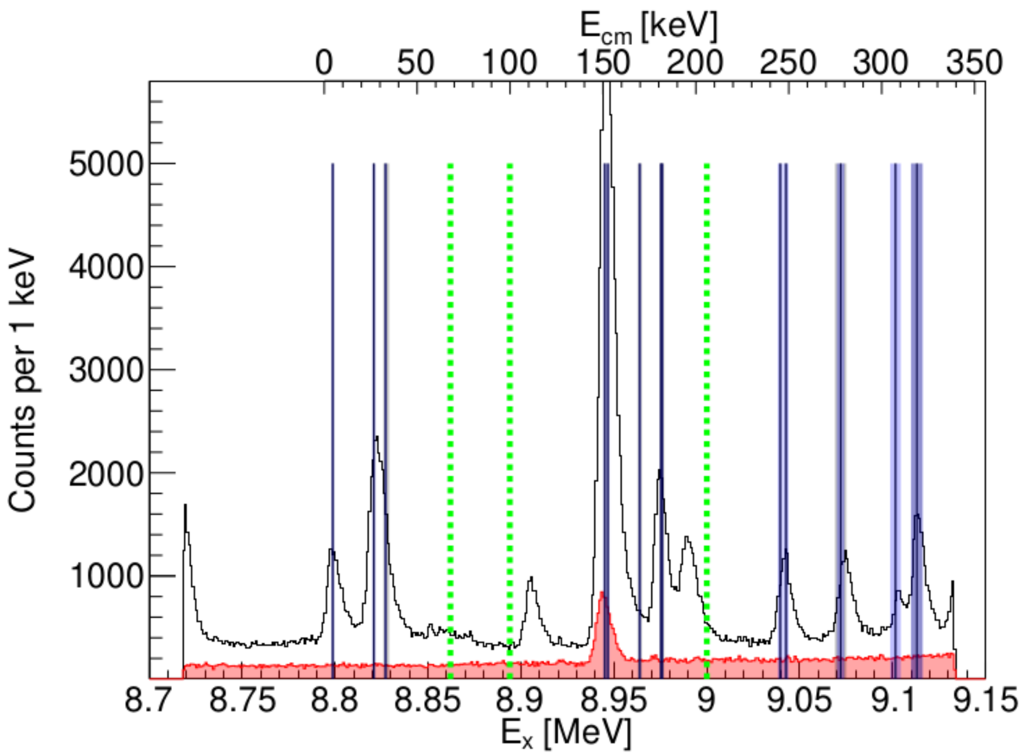

Fig. 1. The excitation-energy spectrum in ^{23}Na following the ^{23}Na(p,p') reaction. The excitation energy is given on the bottom axis and the centre-of-mass energy of the ^{22}Ne+p system on the top axis. The green dashed lines show the positions of the tentative states in ^{23}Na which may enhance the reaction rate. The black lines show the energies of known ^{23}Na levels and the grey/blue boxes show the uncertainties from (grey) literature and (blue) the present experiment.