Direct mass measurement of ^{45}Cr and its impact on Ca-Sc cycle in X-ray burst*

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The experimental program on mass measurements of exotic nuclei has been continued at the storage ring CSRe in Lanzhou by addressing neutron-deficient ^{58}Ni projectile fragments. Masses of ^{41}Ti, ^{45}Cr, ^{49}Fe and ^{53}Ni were measured by applying the isochronous mass spectrometry technique [1, 2]. Details of the experiment can be found in Ref. [3]. It turned out that the mass of ^{45}Cr nucleus has an affect on the modelling of the astrophysical rapid proton capture process (rp-process) of nucleosynthesis in X-ray bursts.

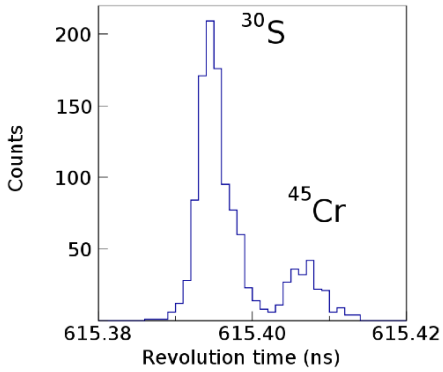

Figure 1: Revolution time spectrum zoom in at ^{30}S and ^{45}Cr.

In total 218 bare ions of ^{45}Cr were collected, see Figure 1, and a statistical mass error of 16 keV was achieved for ^{45}Cr. A special data analysis method was conducted to account for a possible contamination by a recently discovered isomeric state ($E_x = 107$ keV) [4], which resulted the final mass excess of $ME(^{45}\mathrm{Cr}) = -19515(35)$ keV.

Signal zone X-ray burst model [5] calculation was carried out to test the impacts of new masses on the rp-process. With our new mass value the matter flow through ^{43}Ti could be constrained [6].

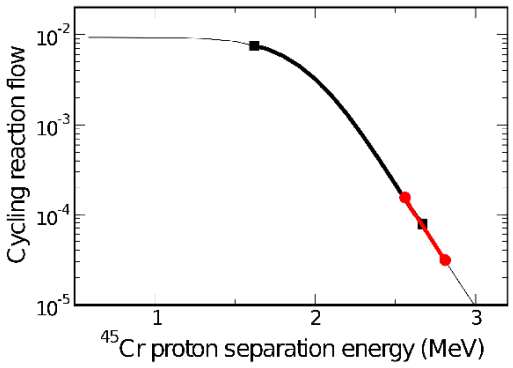

Figure 2: Time intergrated reaction flow through the Ca-Sc cycle during an X-ray burst as a function of $S_p(^{45}\mathrm{Cr})$. The graph spans the 3σ uncertainty of $S_p(^{45}\mathrm{Cr})$ in AME 2003. The thick black line limited by filled squares indicates the 1σ uncertainty of $S_p(^{45}\mathrm{Cr})$ in AME2003, while the thick red line limited by filled circles indicates the 1σ uncertainty when using the experimental data from this work. Taken from Ref. [6].

For a low ^{45}Cr proton separation energy, ^{45}Cr(γ,p) reaction becomes effective, hampering the proton capture flow at ^{43}Ti. As a result, a significant β-decay branch develops at ^{43}Ti driving the reaction flow into ^{43}Sc, which follows by a ^{43}Sc(p,α)^{40}Ca reaction. Thus a so-called Ca-Sc cycle can be forms [7]. With our new ^{45}Cr mass value, a p-capture on ^{44}V becomes effective and a formation of a strong Ca-Sc cycle is practically excluded, see Figure 2.

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