First in-beam test of the CUP

a preliminary report

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1 Introduction

A newly constructed charged particle scintillator detector, designed for use as a veto device in fusion-evaporation experiments, has been for the first time tested in-beam. The detector has been already described in the Appendix to the Euroball proposal *Direct measurement of proton-neutron matrix elements with respect to the* ^{100}Sn *core by studying excited states in* ^{100}In, by M. Palacz et al.

The primary aim of the test was to determine efficiency of the detector and to check if the ability to provide a charged particle veto signal is hampered by the sensitivity to electrons, γ-rays, and scattered beam particles.

The proton and α-particle efficiency $\epsilon_{p,\alpha}$ can be determined as:

$$\epsilon_{p,\alpha} = I^{p,\alpha}_{CUP} / I^{p,\alpha}_{total}$$

where

$I^{p,\alpha}_{CUP}$ — intensity of a γ-ray line from a nucleus produced with the emission of 1 proton or α-particle, respectively, measured in spectrum gated by the CUP detector,

$I^{p,\alpha}_{total}$ — total intensity of the same γ-ray line.

If the detector produces false veto signals (due to electrons, γ rays, beam particles, noise, etc.), the intensity of a line produced without emission of charged particles I^{n}_{total} is reduced by a factor g equal to:

$$g = I^{n}_{not-CUP} / I^{n}_{total}$$

where $I^{n}_{not-CUP}$ is the intensity of the same line measured in anti-coincidence with the detector.

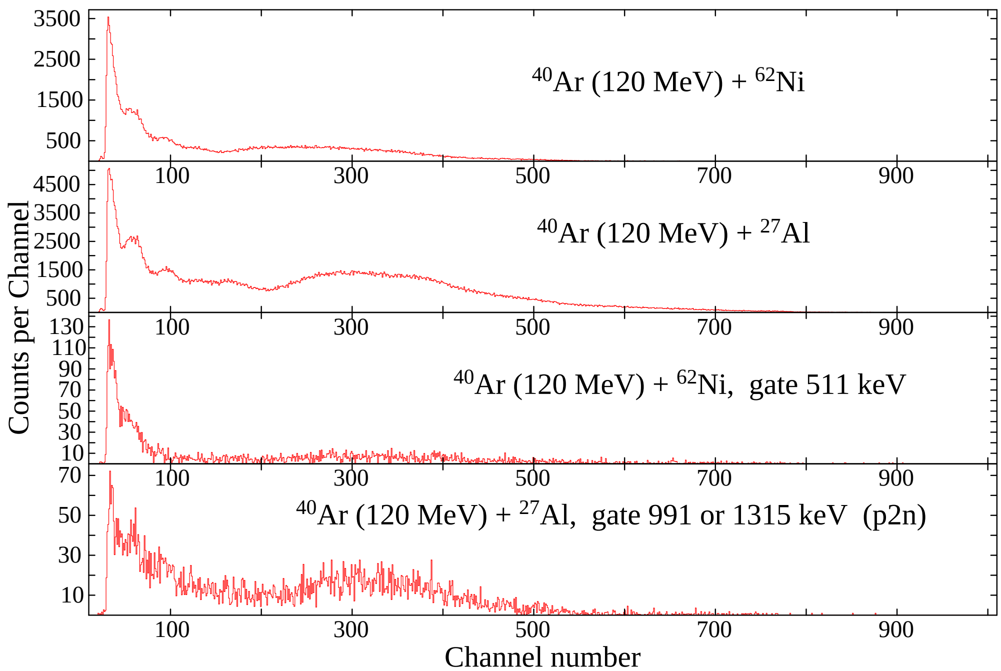

Figure 1: CUP spectra collected during the test experiment

2 Experimental details

The test setup consisted of the CUP and 1 Germanium γ-ray detector placed about 5 cm from the target. A ^{40}Ar beam with the energy of 120 MeV was provided by the Warsaw Cyclotron. Two targets were used: ^{27}Al (9.7 mg/cm^2 thick) and ^{62}Ni (12.5 mg/cm^2). The targets were thick enough to stop all the beam particles. In all CUP experiments, beam has to be stopped in the target in order to avoid scattering of beam particles into the scintillator. On the other hand, target should not be thicker than it is absolutely necessary, because absorption of emitted protons and α particles in the target is the main factor limiting the efficiency of the detector. A cone shaped ^{181}Ta foil was mounted at the downstream side of the ^{62}Ni target in order to stop backscattered beam particles.

Events were stored in a list mode if a γ-ray was registered in the Ge detector, with the CUP photomultiplier anode signal read as a slave. About 1 and 3 million events were collected with the ^{27}Al and ^{62}Ni targets, respectively.

3 Results

CUP spectra collected during the test experiment are presented in Fig. 1. Gamma ray spectra collected with the ^{27}Al and ^{62}Ni targets are shown in Figures 2 and 3, respectively.

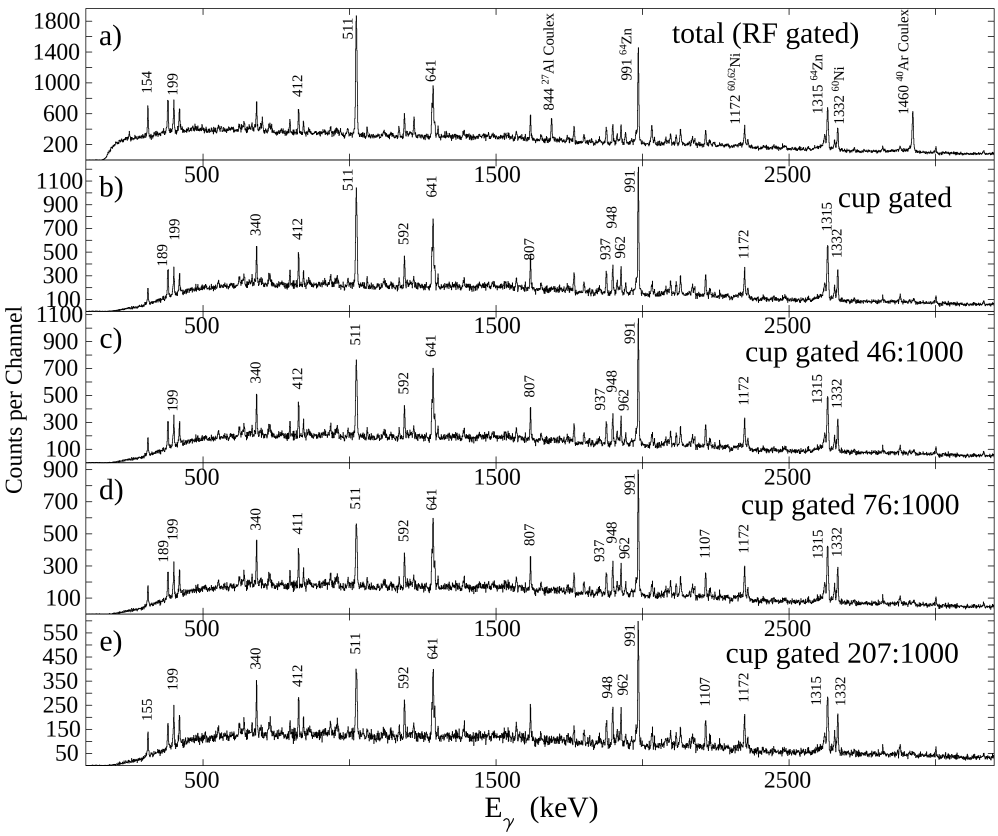

Figure 2: Gamma ray spectra collected with the ^{27}Al target. CUP gated spectra in plots c), d) and e) were obtained with the increased lower threshold value for the CUP signal. The threshold values are marked in the plots and correspond to the CUP energy spectra shown in Fig. 1.

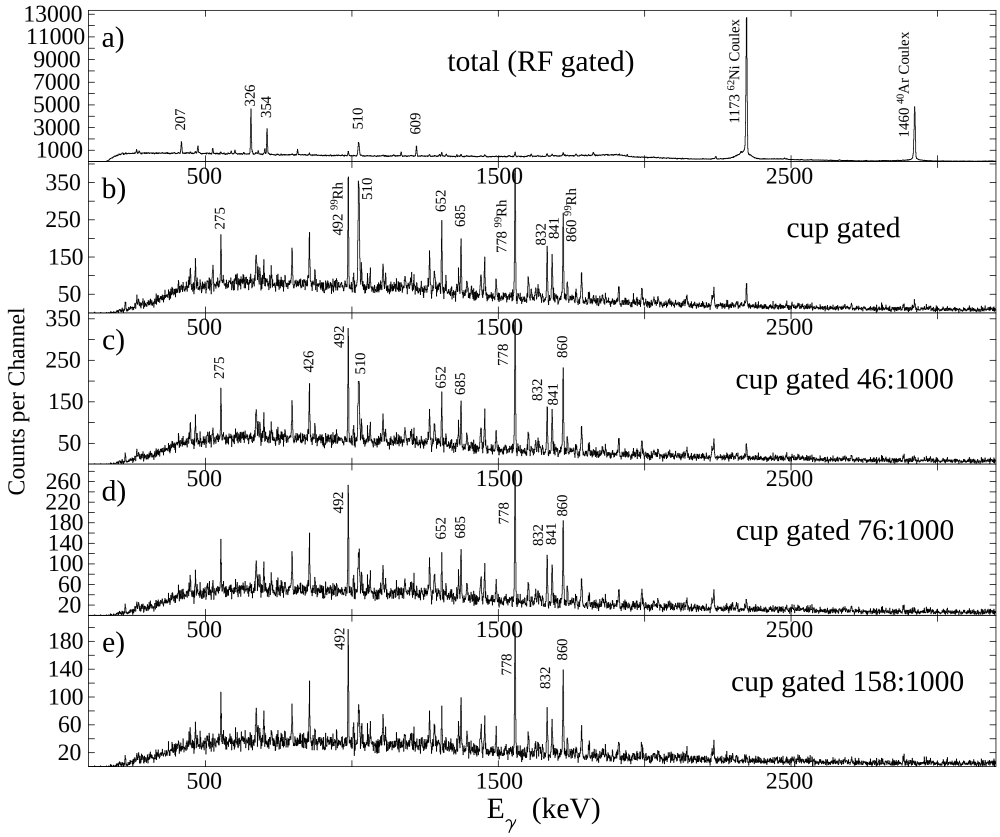

Figure 3: Same as Fig. 2, but for the ^{62}Ni target.

Basing on the collected data we make the following observations:

- The strong Coulex lines (almost) completely disappear when coincidence with the CUP is required. There is thus no indication of false coincidence signals due to low energy γ-rays (beam, target X rays) or δ electrons. The probability to observe a Coulex event in coincidence with the CUP is about 0.4 % and less than 3% for the ^{62}Ni and ^{27}Al targets respectively.

- Increasing the CUP energy threshold improves the selection of lines from the fusion-evaporation reaction, so there is no indication of beam particles hitting the scintillator. We expect that such beam particles would generate exceptionally large signals in the scintillator.

- The proton efficiency is $\epsilon_p = 0.88$ and $\epsilon_p = 0.75$ for the ^{27}Al and ^{62}Ni targets, respectively. These numbers are in both cases determined using lines from the 1p2n evaporation channels (^{64}Zn and ^{99}Rh) which are the strongest channels observed in the reactions. Lower ϵ_p value in case of the ^{62}Ni target is due to the fact that protons are stopped in the ^{181}Ta absorber foil.

- Determination of the particle detection efficiency for other, weaker evaporation channels which also include α particles is more uncertain. We preliminarly estimate that $\epsilon_\alpha = 0.8 - 0.6$ with the ^{27}Al target and it is slightly lower in the case of the ^{62}Ni target.

- We can not identify lines from nuclei produced with the emission of neutrons only, neither in the total, nor in the spectra obtained with the CUP anti-coincidence condition. We can not thus determine value of the factor g defined in the introduction.

  Statistical calculations using the evapOR code predict that such neutron-only channels (3n and 4n) in the case of the ^{62}Ni target should constitute about 30% of the evaporation cross section. Identification of weak lines in the total spectrum and in the CUP anti-coincidence spectrum is hampered by the very large Coulex background. We also checked that neutron only lines are not visible in the CUP gated spectra. Observation of neutron only lines in the CUP gated spectra would indicate that the device in fact selects all kinds of fusion-evaporation events, not only events with charged particles emitted. We note that the neutron-only channels must be anyway much weaker than predicted by evapOR.

- The detector is sensitive to positrons from the $\beta+$ decays and (presumably) electrons of similar energy (a few MeV). Total number of prompt events in which a positron is detected in coincidence with a γ-ray is however small in comparison to the number of events in which protons and α-particles are detected (the intensity of the 511 keV line vs. total intensity of all ground state feeding γ-ray lines in the CUP gated spectrum). The β-decay background should not significantly affect the quality of the veto signal.

4 Conclusions

In conclusion, the results of the tests tentatively indicate that the performance of the CUP meets the design criteria. In case beam time is allocated to EB+NWall+CUP experiments, further in beam tests will soon be performed in order to confirm present results and to optimise the performance of the detector, before it is used with EUROBALL. In particular, the device will be tested with reactions in which neutron-only evaporation channels dominate, so we can properly determine the influence of the anti-coincidence gate on the intensity of γ-ray lines from such channels.