A note on light particle calibration with CsI(Tl) scintillators of the CHIMERA array


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Abstract – Alpha particle energy calibration of CHIMERA CsI(Tl) detector was performed using CS beams. A comparison with proton energy calibration shows unexpected missing quenching effect. This effect is due to a peculiar behaviour of the CHIMERA electronic chain as shown by a comparison performed using digital GET electronics.

INTRODUCTION

It is well known that the light response of scintillators to charged particles is depending from their charge. Heavy Ions with high specific energy loss produce a smaller light output than light particles. This is the so called quenching effect. In order to take into account the charge and mass dependence of the energy-light response function of detectors one can use a formula suggested by Horn [1]

\[ L = a_0 \left( E - a_2 AZ^2 \ln \left( \frac{E + a_1 AZ}{a_1 AZ} \right) \right) + a_0 \]

where A, Z and E are respectively the mass, charge and energy of the detected fragment, L is the collected light signal, \( a_0 \) is a parameter depending on pedestal, \( a_1 \) is connected to the electronic gain of the channel and it includes also the scintillation efficiency of the detector, \( a_2 \) is related to the Birks quenching factor [2]. This formula is based on the assumption that the quenching of CsI(Tl) light output depends on the specific energy loss of the particle dE/dx (Birks prescription). Using this prescription we find in previous work [3] an average systematic correction of the order of 10% for the energy calibration for proton and alpha particles around 60 MeV. More recently during the INKIISSY campaign we were able to directly compare energy calibration obtained with proton and alpha particle beams delivered at LNS by the superconducting cyclotron, and surprisingly we observed a practically charge-independent energy calibration for the two different particles. This confirms previous observations obtained during the GSI ASYEOS experiment where punching trough proton and alpha particles were found to produce the same energy calibration [4]. In this short report we will explain this effect using results of a recent investigation with the new digital GET electronics [5].

COMPARISON OF ALPHA AND PROTON CALIBRATION

A direct proton and alpha particle calibration was obtained in 2013 during the INKIISSY experimental campaign [6] using proton beams of 62 MeV and alpha particle of 35 AMeV impinging on various targets from gold to proton and using a pulser to verify linearity and determine the pedestal position. In fig. 1 we plot an example of the energy calibration obtained for a CHIMERA CsI(Tl) [7] obtained by a standard peak
sensitive analyzers (see below). The different points are explained in the figure. The data set of the different particles can be practically described by an unique calibration line. Quenching is not at all observed, on the contrary in this detector, as in many others, alpha particles show tendency to have a larger light response (measured in qdc channels in this picture) than protons. It useful to understand this behaviour that was already noted in a previous experiment performed at GSI always with CHIMERA CsI(Tl). During the ASYEOS [8] experiment in fact a calibration was obtained using punching trough particles relative to Z=1, Z=2 and Z=3 elements with reasonably good linearity results [4].

DIGITAL ACQUISITION DATA

During recent tests of the new GET electronics we were able to understand the small light deficit of protons with respect to alphas as due to ballistic effects. The GET electronics will substitute the old (with tendency to be obsolete) electronics of CHIMERA CsI(Tl), and it will be also used for the FARCOS array. It is a digital electronics better described elsewhere in this report [5]. Using this electronics we measured the reactions induced by proton beams at 62 MeV on various targets collecting a variety of particles from different reaction mechanisms. The shape of preamplifier signals was stored for the analysis. Digital filter where used to extract the maximum of the signal (assumed proportional to the energy released by the particle or the light response of the detector) and other information like the rise time of the signal, useful for particle identification. We were able to calibrate data, in proton equivalent energy, using various elastic and inelastic scattering from gold, carbon, proton and deuteron targets. Using such calibrations we selected signals of different identified particles but producing the same light in the scintillator to observe their corresponding rise time. This is shown in fig.2. From the observation of this figure, one immediately note that, the rise time of alpha particle signals is much smaller than the one of proton deuterons and γ-rays. The maximum of the signal with these particles is reached after more than 6 µs. The preamplifier signal in the standard electronics is sent to a SILENA spectroscopy amplifier set with a shaping time of 2 µs. It is clear that the very slow signals produced by proton and γ-rays can produce a ballistic deficit due to 2 µs amplifier filter that was much larger than the one produced by alpha-particles. This effect was responsible of the apparent inverse quenching effect observed in fig.1 from proton and alpha particles. Such limitations will be avoided by digital DAC systems.

REFERENCES