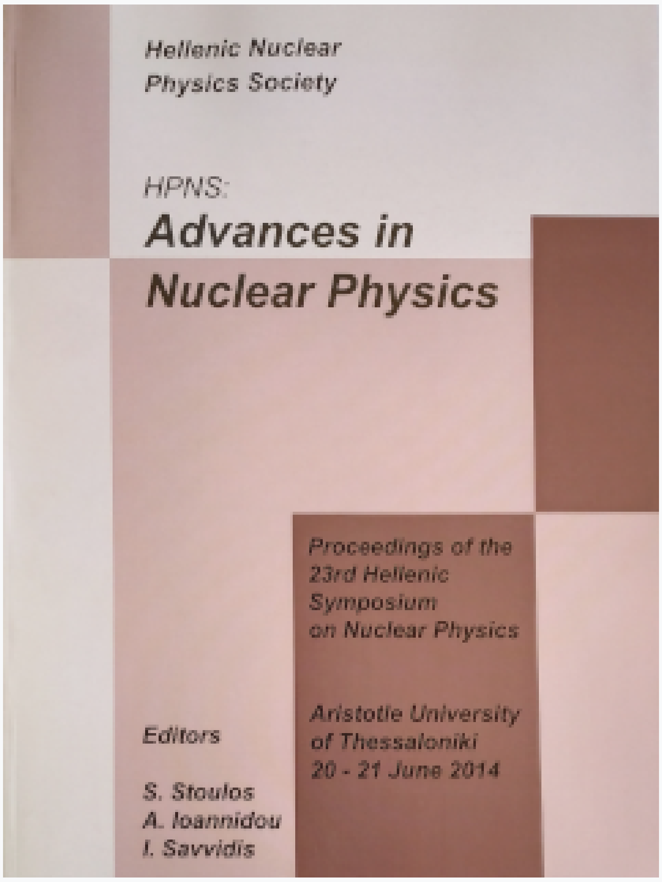
HNPS Advances in Nuclear Physics

Vol 22 (2014)

HNPS2014



Benchmarking the proton elastic scattering cross sections on 19F and natB using ΔE/E silicon telescopes

A. Stamatopoulos, M. Axiotis, M. Kokkoris, A. Lagoyannis, V. Paneta, R. Vlastou

doi: 10.12681/hnps.1917

Benchmarking the proton elastic scattering cross sections on ^{19}F and ^{nat}B using ΔE/E silicon telescopes

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Introduction

Proton EBS, the most widely used IBA technique for light element depth profiling, requires accurate differential cross section data, which need to be validated. Among other difficulties (proper selection of suitable thick target, elimination of all corresponding uncertainties etc.), this validation is often impeded by background contributions from (p,α) reaction channels (as shown in fig. 1 in the case of a thick ^{nat}B target yield spectrum acquired at 160°, for E_p=2.8 MeV), therefore a high precision procedure to benchmark theoretically evaluated cross sections as well as existing experimental ones, in the absence of evaluated data, is of vital importance. In this framework, a DAQ system interface has been developed, based on CAMAC electronics, using SSB detectors, resulting in thick target yield spectra suitable for the benchmarking of the elastically scattered protons, eliminating eventually all the corresponding contributions from the (p,α) reaction channels.

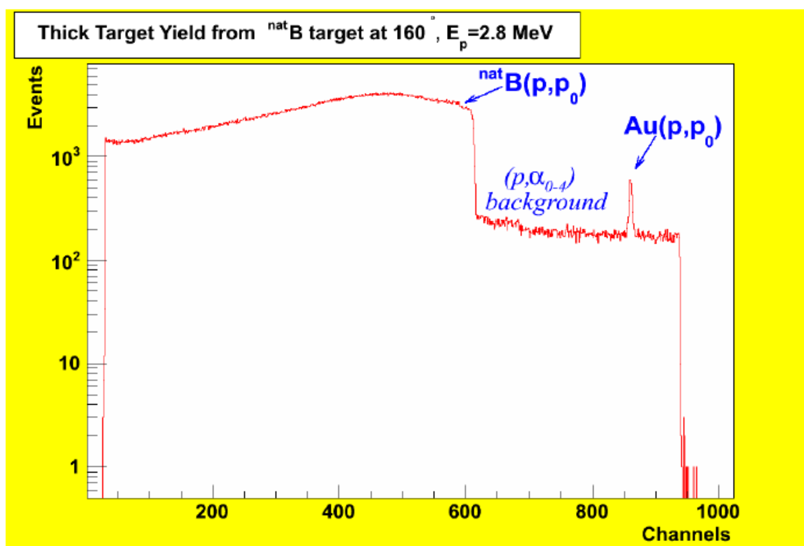

Figure 1 : Thick Target Spectrum from ^{nat}B(p,p) acquired at 160°, at beam energy, 2.8 MeV. The (p,α) *background is visible as well as the thin Au layer, evaporated on the target for normalization purposes*

The ΔE/E technique implementation

To implement the ΔE/E technique, apart from the standard CAMAC and NIM electronics, a proper event-by event Data Acquisition Software had to be developed. Such a software was built in-house, using Sparrow's Kmax 7 platform, in Java™, along with a relevant off-line sorting and data selection code, using CERN's data analysis framework, ROOT.

The trigger logic was based solely on the E signals, due to solid angle and noise reduction considerations, such as random coincidence among the noisy ΔE detectors. An example of the graphical user interface is illustrated in fig. 2a. As built, it can support 6 detectors and plot in-beam mode 2D histograms, combining 2 telescope channels. The GUI is equipped with useful functions that the user may need such as spectrum calibration, peak integration, ADC threshold adjustment etc as illustrated in fig: 2b.

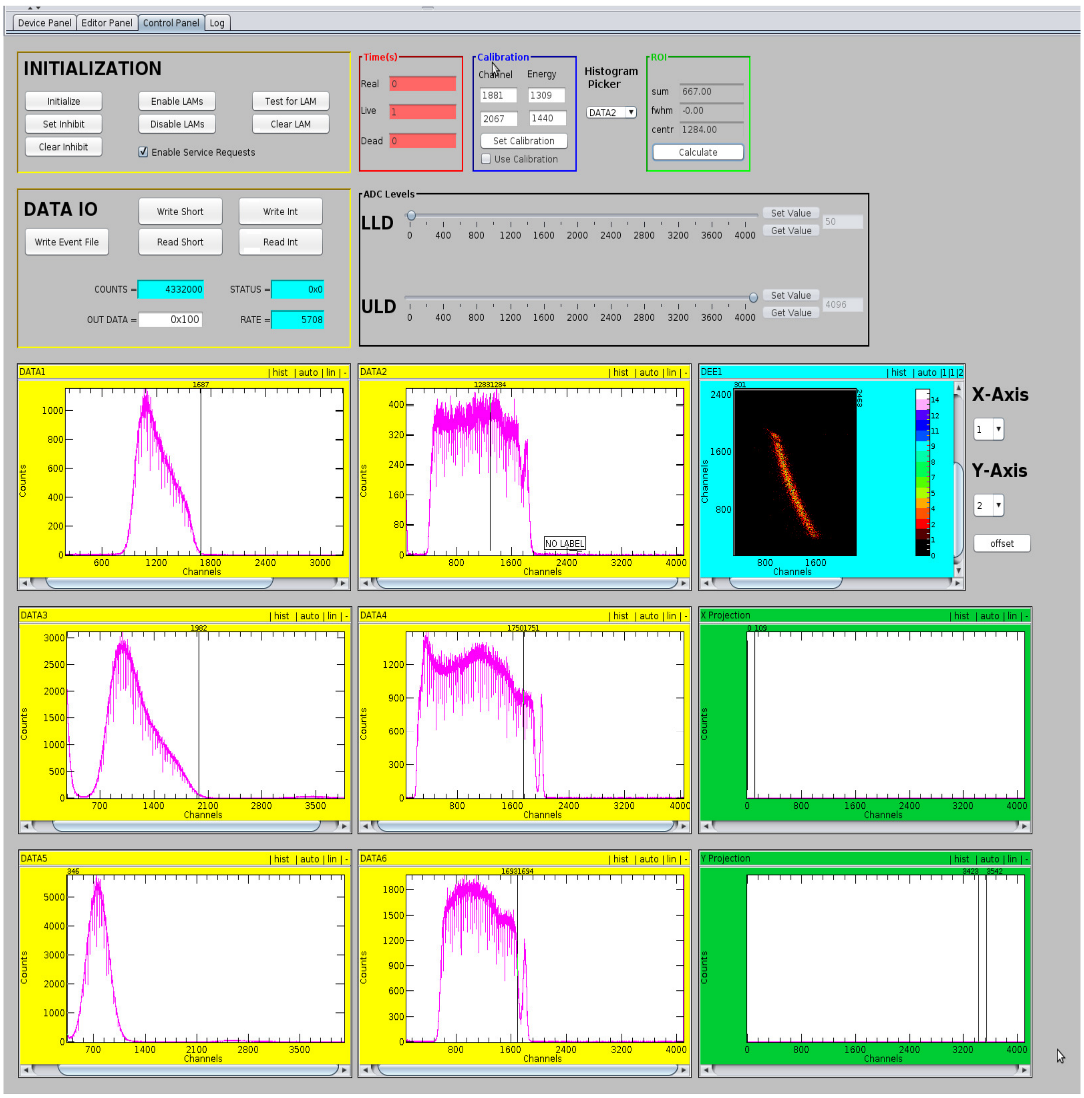

Figure 2*a* : Graphical User Interface's Screen Shot of the CAMAC Data Acquisition System that has been developed for the need of the measurements

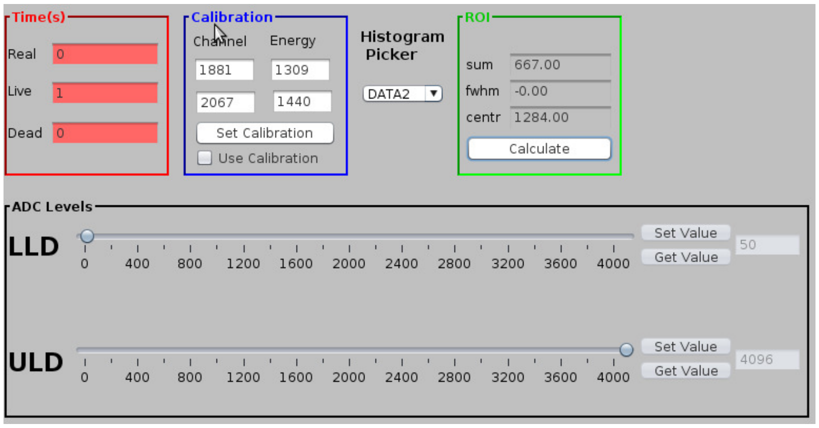

Figure 2b: The DAQ interface is equipped with useful functions, such as peak integration, spectrum calibration and ADC threshold adjustment

Analysis

To test the new DAQ system, experiments were performed using the proton beam of the 5.5 MV TN11 HV Tandem Accelerator of N.C.S.R. "Demokritos", Athens, Greece. The protons, accelerated to $E_{p,lab}$=1500–3300 keV, were led to a large size cylindrical scattering chamber (R~40 cm), whose interior can be seen in fig.: 3.

The detection system includes six Si surface barrier detectors, grouped in three pairs, as illustrated in fig: 3. Each pair of ΔE/E consists of a thin (6, 13, 22 μm) and a thick detector(1000 μm) placed at 170^o, 150^o and 120^o along with the corresponding CAMAC and NIM electronics. The beam spot size was ~2 mm in diameter, while the current on target did not exceed ~5 nA during all measurements, in order to avoid pileup effects. The spectra from all the detectors were simultaneously recorded and the procedure was repeated for every $E_{p,lab}$. As shown in Fig. 3, small cylindrical tubes (of ~2 cm in diameter) were placed in front of the ΔE detectors in order to eliminate background contributions from beam particles scattered in the chamber walls and/or target frames.

The thick targets used in the experiment, were highly pressurized pellets of ZnF_2 and ^{nat}B with a thin layer of gold (~1keV) evaporated on top for protection and normalization purposes. This is common practice for the accurate determination of the QΩ product when deviations from the Rutherford formula for elastic scattering are expected, as in the case of boron (even at very low proton beam energies) and zinc (for E_p above ~2.8 MeV, as reported in [1]) .

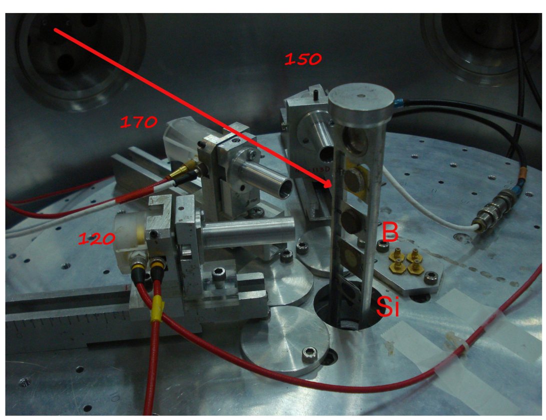

Figure 3 : The three Si Telescopes installed at 120^o, 150^o, 170^o inside the scattering chamber along with the ^{t}B

Following acquisition, the raw data, from each telescope (fig. : 4), were analyzed event-by-event and were sorted in 2D histograms forming the particle identification curves or “banana” curves (fig. : 5a). A careful selection of the useful data, is projected to form the spectrum that the E detector has read (fig.: 5b). This spectrum is clean of the parasitic (p,α) channels, thus it can be further analyzed in widely used RBS/EBS/NRA programs such as e.g. SIMNRA [2], This procedure is repeated for all telescopes, angles and energies.

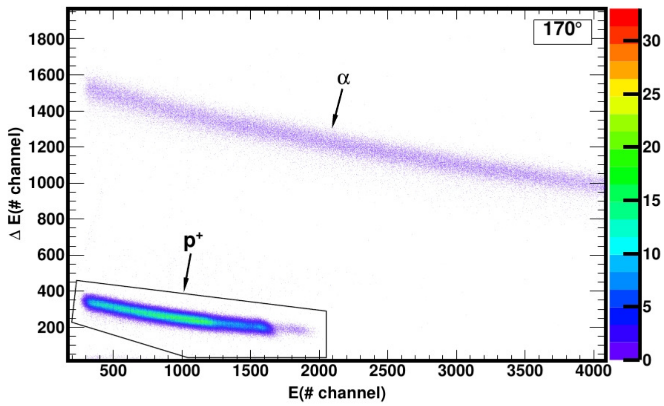

Figure 5a: *Particle identification curves for protons and α-particles, acquired by the Data Acquisition System.*

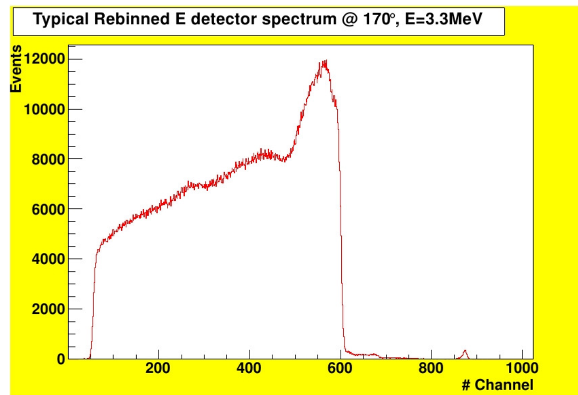

Figure 5b: *Projected proton spectrum form E detector, after selecting the proper particle region, inside a 5-point area*

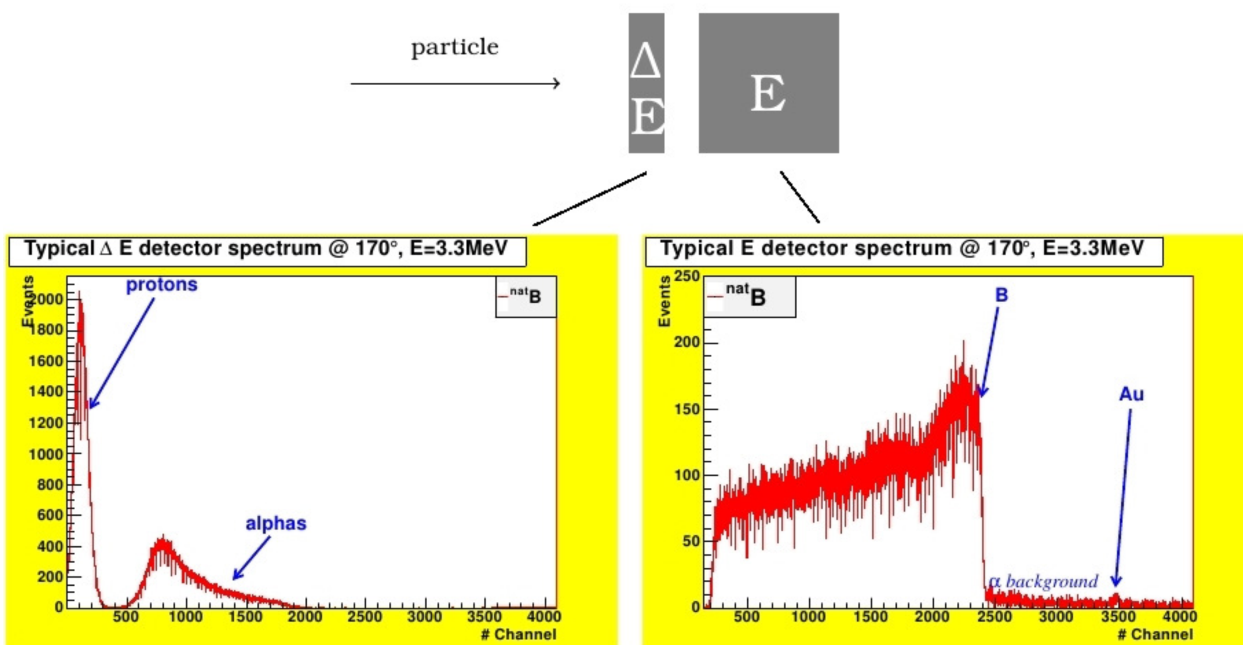

Figure 4: *The raw spectra acquired by the ΔE and the E detector. The different energy loss in the thin ΔE detector for protons and α- particles is clearly visible.*

In detail, the sorting and off-line analysis code, accepts as input the data file produced by the Data Acquisition System, and sorts all ADC values in 1D histograms, recreating the raw spectra that each detector has recorded(fig.: 4). Then each spectrum is sorted in a 2D histogram, with ΔE on y-axis and E on x-axis, constructing the particle identification curves(fig.: 5a). To acquire the without α-particles E spectrum, a 5-point region is defined around the proper curve followed by the projection along x-axis. Following the standard counts/channel guidelines, all spectra acquired by the 4096-channel ADC, are rebinned to 1024 channels (fig.: 5b). Finally the code exports the projected and rebinned histogram in ascii format for further analysis in relevant frameworks.

A preliminary analysis, at 170^o in the ^{19}F case, indicates that strong deviations exist between the experimental benchmarking spectra [3] and the simulated ones using both evaluated (SigmaCalc 2.0 [4]) and experimentally determined differential cross sections (A.P. Jesus [5]) over a broad energy range. However, it should be noted that in this test run no accurate energy calibration of the ΔE detector was performed, thus it was practically used as an absorber foil. This is expected to have serious implications in the simulation procedure, due to energy and lateral straggling effects which cannot be fully reproduced with high accuracy, despite the existence of various models widely implemented in literature (e.g. Bohr, Chu, Chu & Young). A future run has already been scheduled, using the same targets, in order to clarify this remaining issue.

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Aknowledgements

This work has been supported by the European Community and the Greek Government through the project 'IKY scholarships' and ESPA 2007-2013 by contract no. 2013-ΕΣΠΑ-ΠΕ3-1991.