Optimization of the boron analysis system using a DSSSD at LIBAF: What count counts and where?

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Introduction

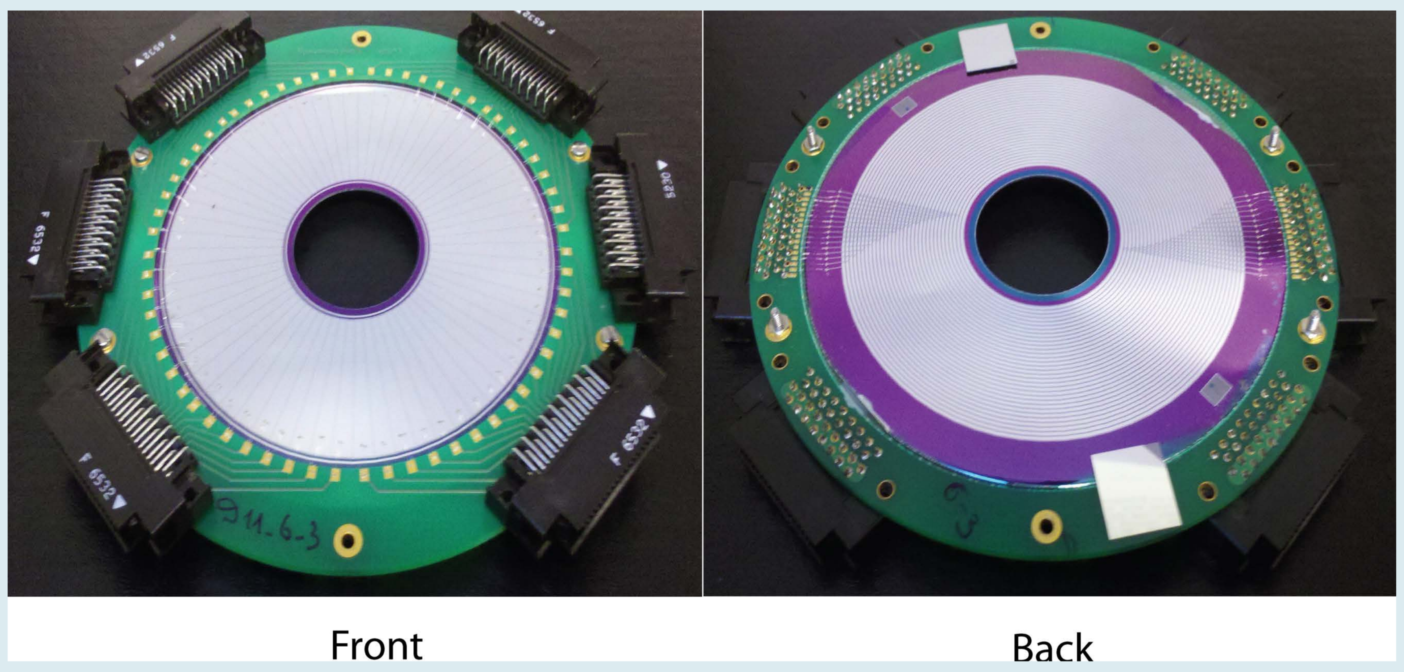
- **Boron analyses of geological samples using Nuclear Reaction Analysis** (NRA) have been conducted at LIBAF for more than 20 years.
- The recent upgrade of the boron analysis system – a **DSSSD with 2048 independent segments** has replaced the single annular surface barrier detector – allows for a much higher beam current (i.e. count rate) to be used, without pile-up issues.
- A study of **the energy dependence and the angular dependence of the boron yield of the nuclear reaction $^{11}B + p \rightarrow 2\alpha + \alpha$** is presented. The reaction has a broad resonance just below 700 keV proton beam energy.
- The purpose of this optimization is to **enable boron analyses in geological samples at least down to 10 ppm.**

Experimental setup

- **Experimental facility:** Lund Ion Beam Analysis Facility (LIBAF)
- **Proton beam energy:** 500 keV – 900 keV
- **Detector:** Double-sided silicon strip detector (DSSSD) [1,2] with 64 sectors on the front side and 32 rings on the back side
- **Reaction studied:** $^{11}B(p, \alpha)2\alpha$
- **Samples:** thick DTA (Datolite Tourmaline Axinite) boron standard, thin boron standard (0,1 μm B on 3,5 μm Mylar), quartz
- **Aim:** energy dependence and angular dependence of the boron yield

Why analyze boron?

- **Boron is commonly present in tourmaline** and other silicate minerals in the Earth's crust, in minor/trace element amounts.
- **Boron is an element of particular interest in geology**, one reason being that boron has a tangible impact on geological processes, e.g. concerning common rock-forming minerals, and may be of greater importance than previously thought.
- **NRA is a suitable method for determining boron content** in geological samples, e.g. as it does not suffer from matrix effects.

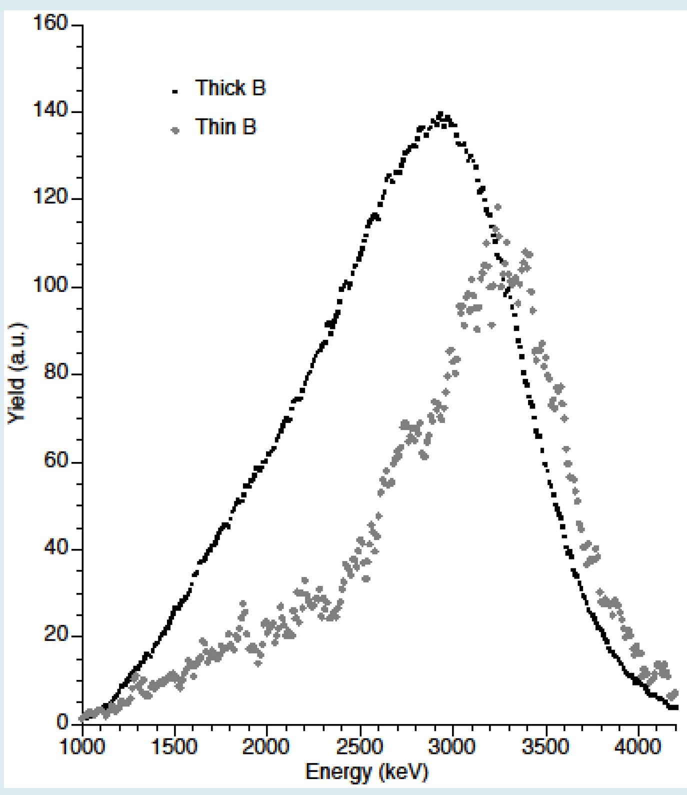


DSSSD with 64 sectors and 32 rings. Photo: Maciek Borysiuk

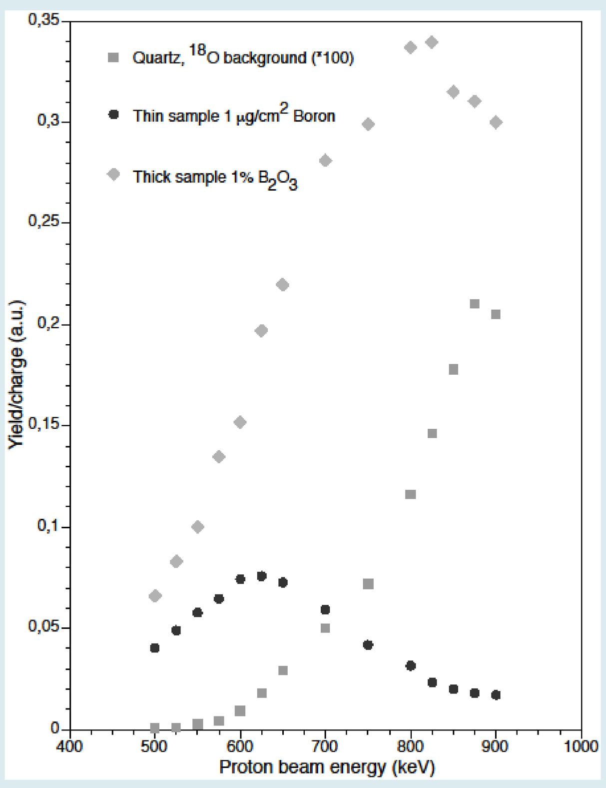
- **Scan:** 128 pixels · 224 pixels
- **DAQ:** New VME based multi-parameter system for data acquisition and control [3]
- **Charge normalization**: Pre-target deflection of beam into Faraday cup [4]

Results: Energy dependence and angular dependence of the boron yield

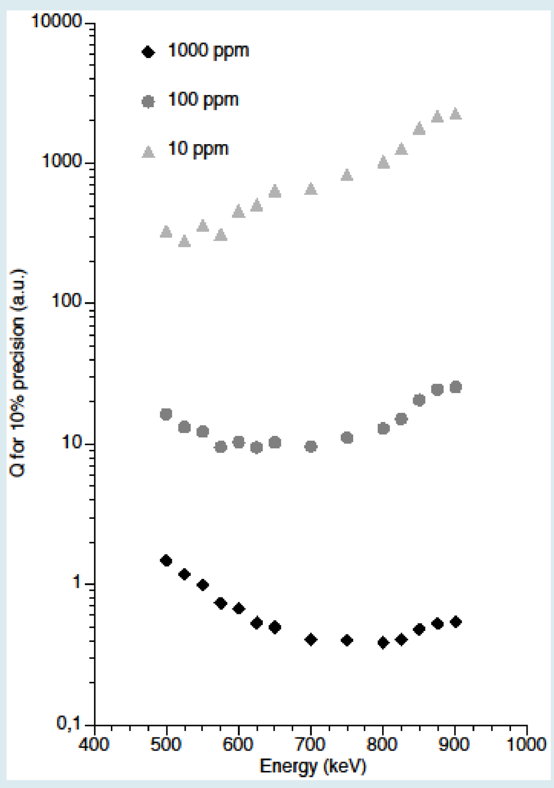
Energy spectrum for B standards at 600 keV proton energy:



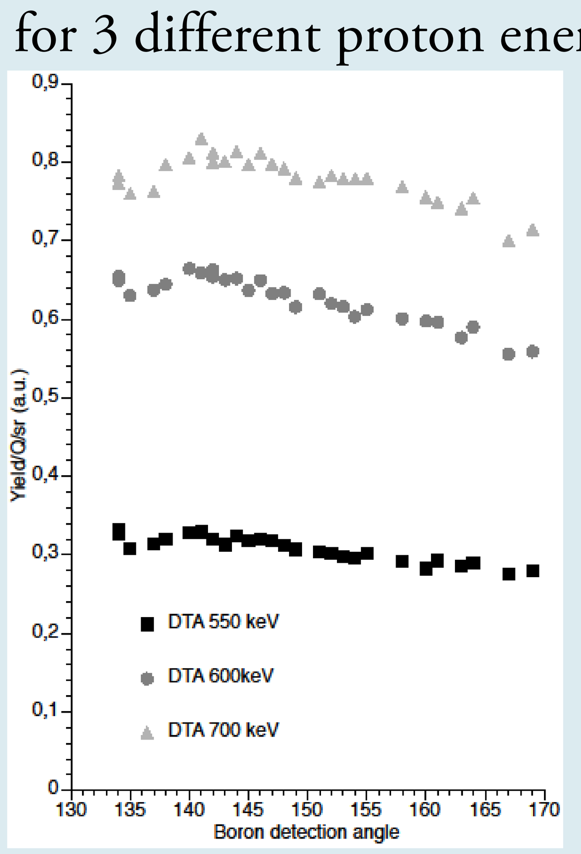
Yield as a function of proton energy for B standards and O background:



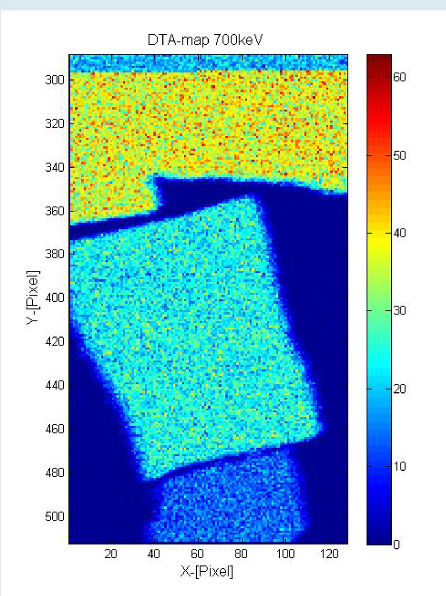
Q for 10% precision as a function of energy for 3 different MDL:



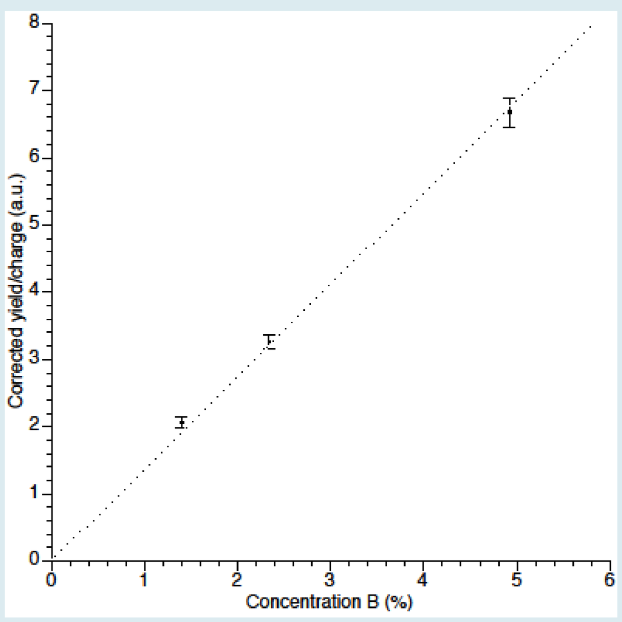
Yield (solid angle corrected) as a function of B detection angle in DTA for 3 different proton energies:



2D map of DTA at 700 keV proton energy:



Calibration curve for boron concentration in DTA:



Conclusion

- Energy dependence of the boron yield: Successful establishment of the amount of deposited charge necessary for 10 % precision for 3 different minimum detection limits (10 ppm, 100 ppm and 1000 ppm) at different proton energies.
- Angular dependence of the boron yield: the yield is essentially angle independent.
- If the statistics are sufficient, parts of the energy spectrum can be selected in order to improve the boron-to-background-ratio.

References

[1] P. Golubev et al. First results from the Lund NMP particle detector system. Nuclear Instruments and Methods in Physics Research B 267 (2009) 2065-2068.

[2] P. Kristiansson et al. The implementation of a DSSSD in the upgraded boron analysis at LIBAF for applications in geochemistry. Nuclear Instruments and Methods in Physics Research B 332 (2014) 207-211.

[3] M. Elfman et al. A tailored 200 parameter VME based data acquisition system for IBA at the Lund Ion Beam Analysis Facility – hardware and software. Presented at IBA 2015.

[4] P. Kristiansson et al. A pre-sample charge measurement system for quantitative NMP-analysis. Nuclear Instruments & Methods in Physics Research B 268 (2010) 1727-1730.

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22nd International Conference on Ion Beam Analysis

IBA2015, June 14-19, 2015 – Opatija, Croatia