

# PIXE-PIGE experiments on archaeological and environmental type samples at the 3 MV Tandetron of IFIN-HH

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Particle Induced X-Ray Emission (PIXE) is a non-destructive ion beam analytical method based on inner-shell ionization of atoms by particle beam of MEV energy, followed by emission of characteristic X-rays. In our laboratory, PIXE is able to determine elements with  $Z \geq 13$  in samples.

Particle Induced Gamma-ray Emission (PIGE) is complementary to PIXE in analyzing light elements with  $Z \leq 14$  (e.g. Mg and Na, of special interest in archaeological glass samples). PIGE is based on  $(p,\gamma)$ ,  $(p,p'\gamma)$ ,  $(p,\alpha\gamma)$  nuclear reactions, with prompt gamma-rays production.

Experiment proposal: to investigate the analytical capability in applying a combination of PIXE-PIGE techniques at the 3 MV Tandetron of IFIN-HH, using different Certified Reference Materials (CRMs). Of interest is determination of major, minor and trace elements concentrations in archaeological and environmental samples (metal, glass, ceramic, as well as soil and vegetation, respectively) prepared as thick targets. Environmental samples are prepared as pellets of homogeneous fine powders.

## Detectors:

- For PIXE (X-ray detection): IGLET-X-06135-S High Purity Germanium (diameter 6 mm, depth 6 mm, Be windows 0.0127 mm) placed in the reaction chamber.
- For PIGE ( $\gamma$ -ray detection): GEM10P4-70 High Purity Germanium (1.75 keV FWHM at 1.33 keV of  $^{60}\text{Co}$ ).

## Reference materials:

- Vegetation: IAEA-V10 (Hay); INCT-MPH2 (Mixed Polish Herbs), INCT-OBTL-5 (Oriental Basma tobacco Leaves), INCT-PVTL-6 (Polish Virginia Tobacco Leaves), Institute of Nuclear Chemistry and Technology, Warsaw, Poland.
- Soil (IAEA).
- Metallic foil and glass (Goodfellow, NIST, USGS).

## Standardization:

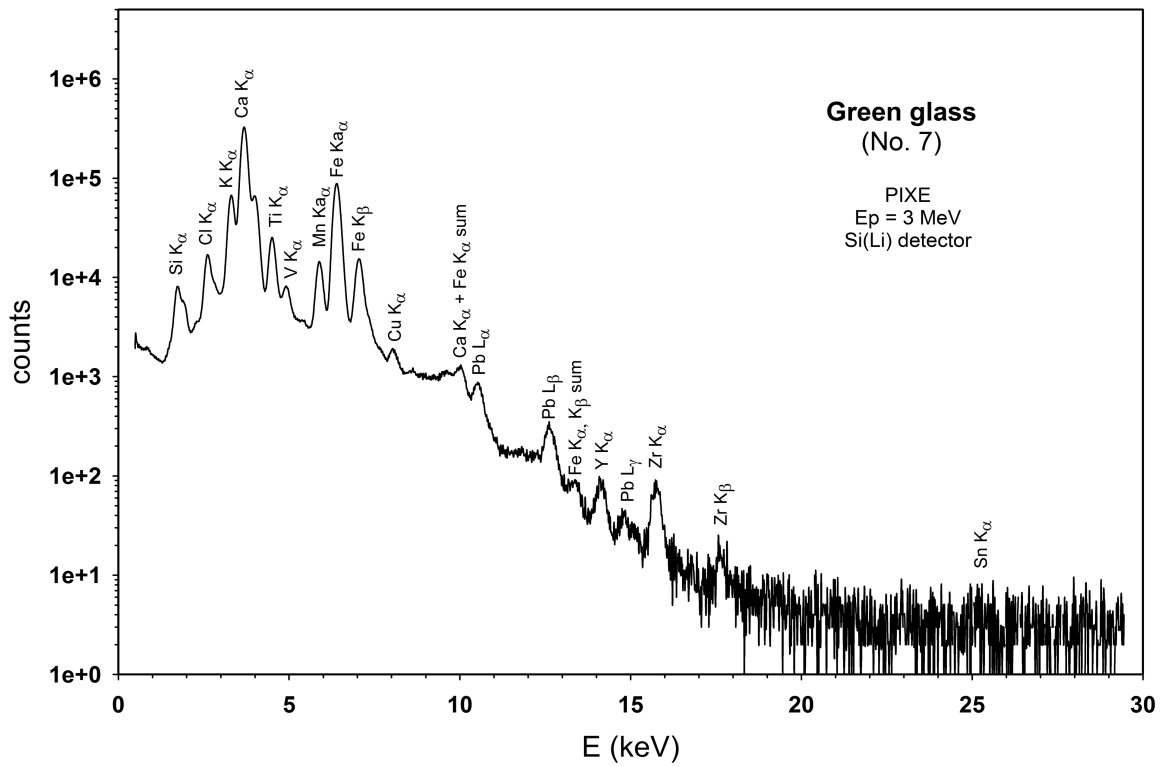
GUPIX (Guelph PIXE) program will be used for quantitative PIXE analysis.

ERYA code (Emitted Radiation Yield Analysis, will be used as a standard-free method for PIGE analysis on thick samples.

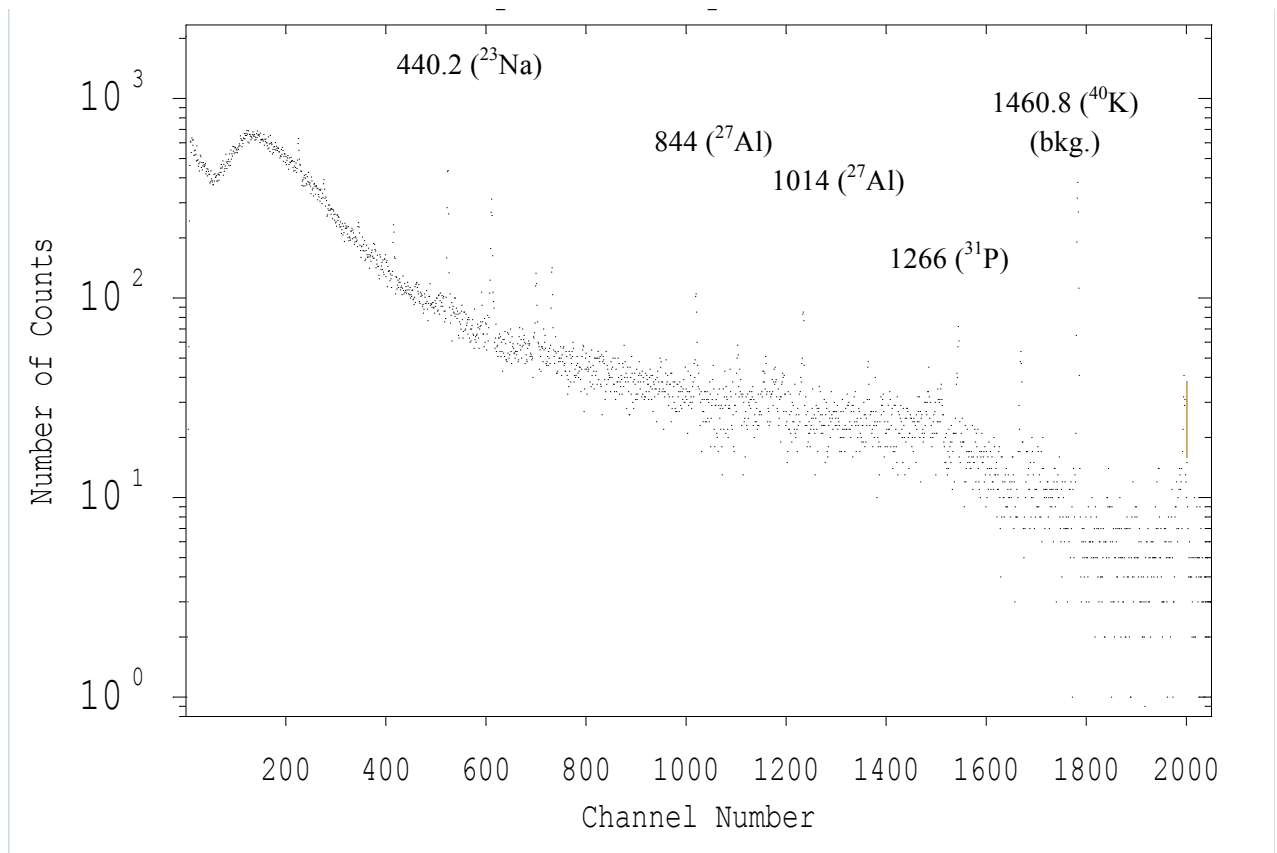
## Example of PIGE reactions:

- $^{23}\text{Na}(p,p'\gamma)^{23}\text{Na}$  ( $E_\gamma = 440$  keV),
- $^{24}\text{Mg}(p,p'\gamma)^{24}\text{Mg}$  ( $E_\gamma = 1369$  keV),
- $^{25}\text{Mg}(p,p'\gamma)^{25}\text{Mg}$  ( $E_\gamma = 390; 585; 974$  keV),
- $^{27}\text{Al}(p,p'\gamma)^{27}\text{Al}$  ( $E_\gamma = 844; 1014$  keV),
- $^{28}\text{Si}(p,p'\gamma)^{28}\text{Si}$  ( $E_\gamma = 1779$  keV).
- $^{31}\text{P}(p,p'\gamma)^{31}\text{P}$  ( $E_\gamma = 1266$  keV).

Attention should be paid to spectral interferences in the case of PIGE (e.g. 585 keV peak of  $^{25}\text{Mg}$   $(p,p'\gamma)^{25}\text{Mg}$  reaction interferes with 583 keV of  $^{208}\text{Tl}$  ( $^{232}\text{Th}$  series) of the natural background).



**Fig. 1.** PIXE spectrum of an archaeological glass sample from Pliska, Bulgaria [1].



**Fig. 2.** PIGE spectrum of a vegetal sample (INCT-MPH-2, Mixed Polish Herbs) at the 3 MV Tandatron of IFIN-HH ( $E_p = 3$  MeV).

## References

- [1] P. Georgiev, I. Penev, G. Tzekova, G. Ilieva, D. Pantelica, A. Pantelica, P. Ionescu, M. Gugiu, D. Fluerasu, C.I. Calinescu, C. Costache, PIXE analysis of some artefacts from the first Bulgarian capital Pliska in IX-XI centuries, P. ECAART-11, 9-13 September 2013, Namur, Belgium, ABS ID: P-109.
- [2] D. Abriola, A. Pedro de Jesus, 1<sup>st</sup> Research Coordination Meeting - Development of a Reference Database for Particle-Induced Gamma ray Emission (PIGE) Spectroscopy (Summary Report), 16-20 May 2011, IAEA, Vienna, INDC (NDS)-0589, <http://www-nds.iaea.org/reports-new/indc-reports/>.
- [3] Z. Šmit, F. Tartari, F. Stamati, A. Vevecka-Priftaj, J. Istenic, Analysis of Roman glass from Albania by PIXE-PIGE method, Nuclear Instruments and Methods in Physics Research B 296 (2013) 7–13.
- [4] Nuclear Instruments and Methods in Physics Research B 269 (2011) 3060–3062, Golden glazes analysis by PIGE and PIXE techniques, M. Fonseca, H. Luís, N. Franco, M.A. Reis, P.C. Chaves, A. Taborda, J. Cruz, D. Galaviz, N. Fernandes, P. Vieira, J.P. Ribeiro, A.P. Jesus.

## **BEAM REQUEST at Bucharest 3 MV TANDEM**

**Experiment Title:** PIXE-PIGE experiments on archaeological and environmental type samples

### **Experiment Responsible**

Num<sup>\*</sup>: Dr. Ana Pantelica; E-mail address<sup>\*</sup>: [apantel@nipne.ro](mailto:apantel@nipne.ro); Phone: 5325

**Short presentation of the scientific project** (maximum four pages): see above

**Beam time request** (unit=8 hours)<sup>\*</sup>: 2 (beam entries) x 9 shifts; Desired Period<sup>\*</sup>: Nov. - Dec. 2013

### **Desired beam properties**

Type<sup>\*</sup>: protons; Energy (MeV)<sup>\*</sup> 3; Intensity<sup>\*</sup>(p/nA): ~ 1nA

Vacuum Requests<sup>\*</sup>: 10<sup>-6</sup> torr

### **Special requirements for detectors, electronics, acquisition system:**

Experimental set-up belonging to PIXE-PIGE-RBS reaction chamber

### **Minimal information needed for the radiological risk evaluation :**

- a) Source activity: <sup>\*</sup> -
- b) Use of open sources<sup>\*</sup> : -
- c) Estimate of the residual activity as a result of irradiation<sup>\*</sup> : -
- d) Means of storage/transportation for irradiated targets<sup>\*</sup> : -