GAMMA-RAY SIGNALS IN NEUTRON ACTIVATION ANALYSIS

ANALYZE - OPTIMIZE - IMPROVE

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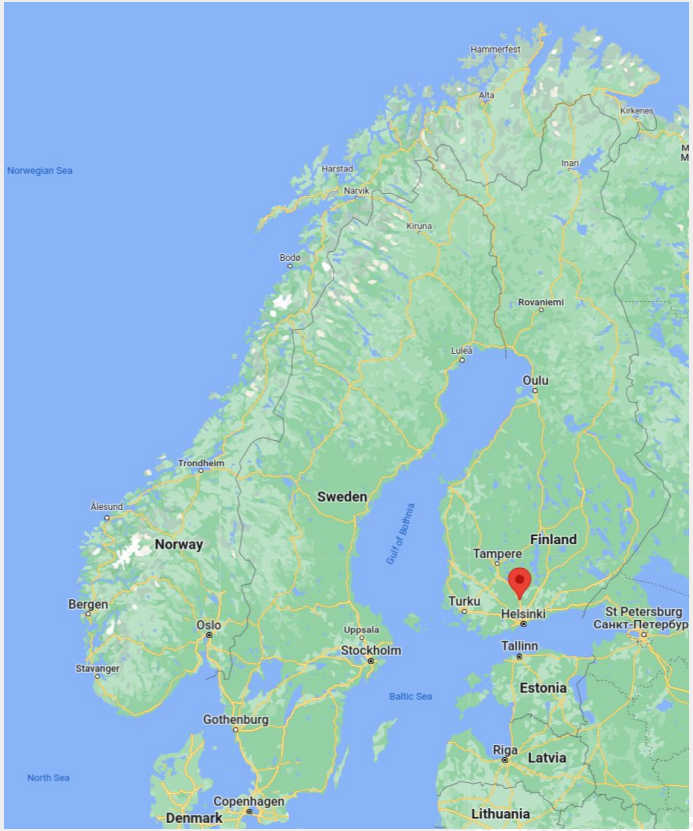
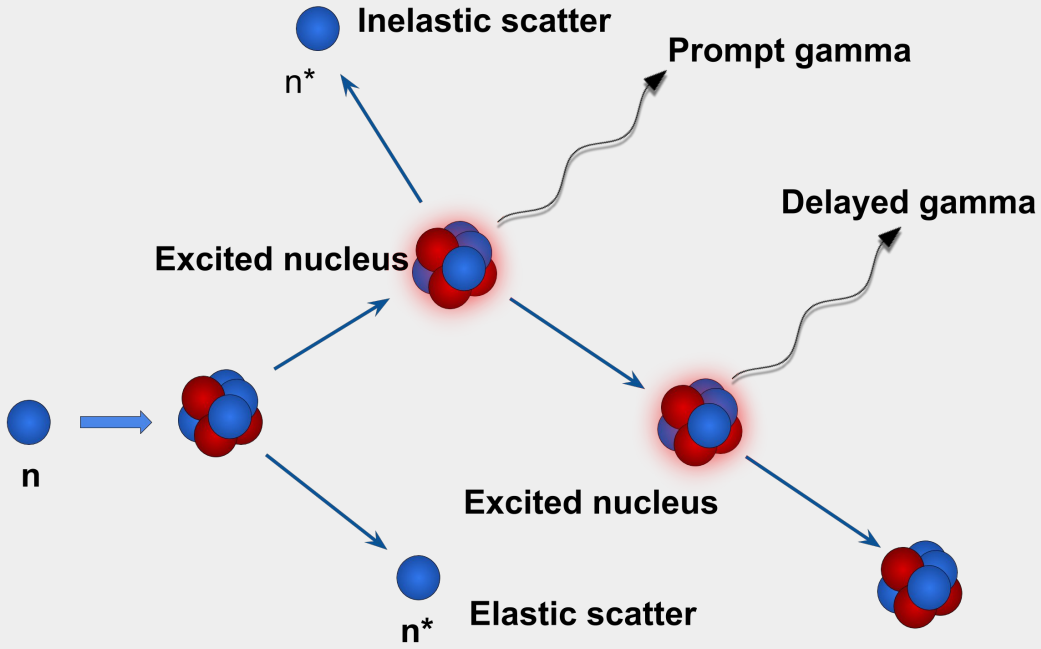
ABOUT NEUTRONGATE

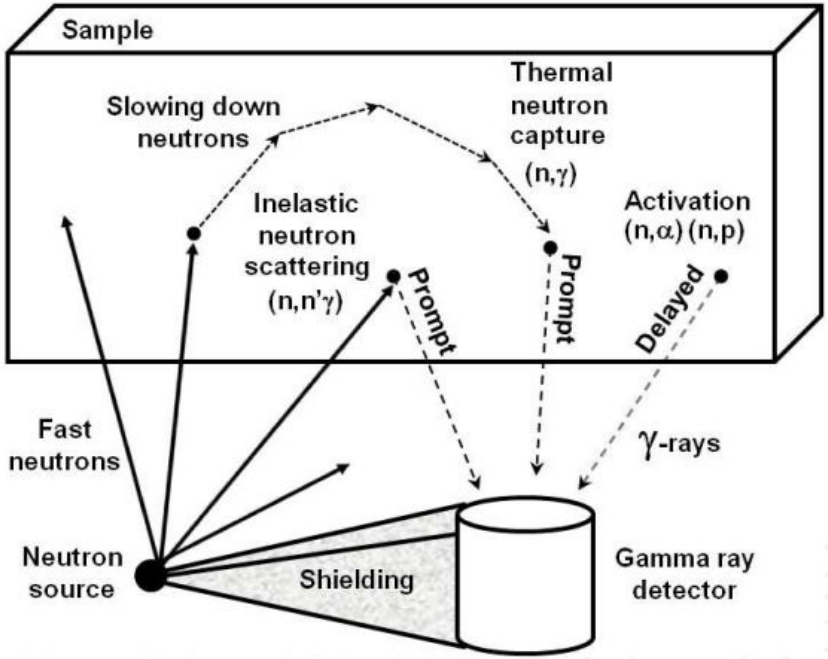
- Located in Riihimäki, 70 km North from Helsinki
- Neutron activation based elemental analysis
  - Instruments
  - Laboratory service
- Inhouse development of neutron generators



NEUTRON ACTIVATION GAMMA RAYS



NEUTRON ACTIVATION ANALYSIS



Alexander P. Barzilov et al (2012). Material Analysis Using Characteristic Gamma Rays Induced by Neutrons ISBN: 978-953-51-0316-5

ELEMENTAL ANALYSIS

PARTS

PLASMA ①
Energy is fed in to low density gas that ionizes via electron collisions forms plasma

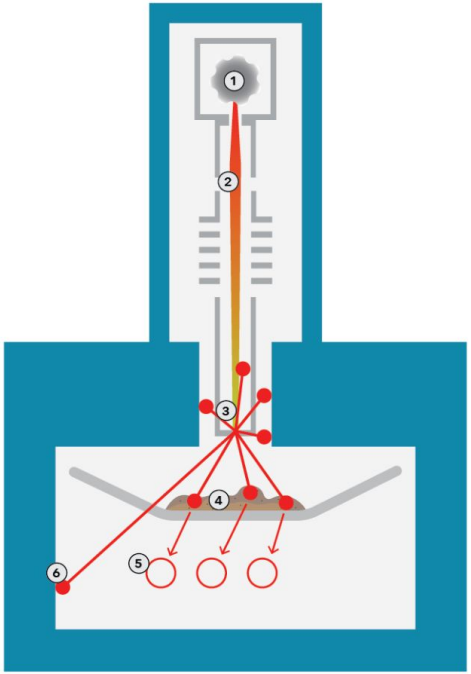
ACCELERATOR ②
Beam is extracted from plasma focused and accelerated to beam target.

BEAM TARGET ③
nuclei collide at the beam target forming neutrons via nuclear fusion

SAMPLE ④
mass on the conveyor is irradiated with neutrons.

DETECTION ARRAY ⑤
Detector array detects the gammas comming from irradiated material.

SHIELDING ⑥
Remainig neutrons are shielded from the environment by radiation shielding



PROCESS

NEUTRON PRODUCTION
Neutron beam is produced by innovative new accelerator produced by NeutronGate

↓

NEUTRON ACTIVATION
Neutrons interact with nuclei in the material flow exiting them and inducing gamma emission that is element specific.

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DATA ACCUISITION
Gamma signals from detector array are filtered and analysed in order to provide raw data and spectrums.

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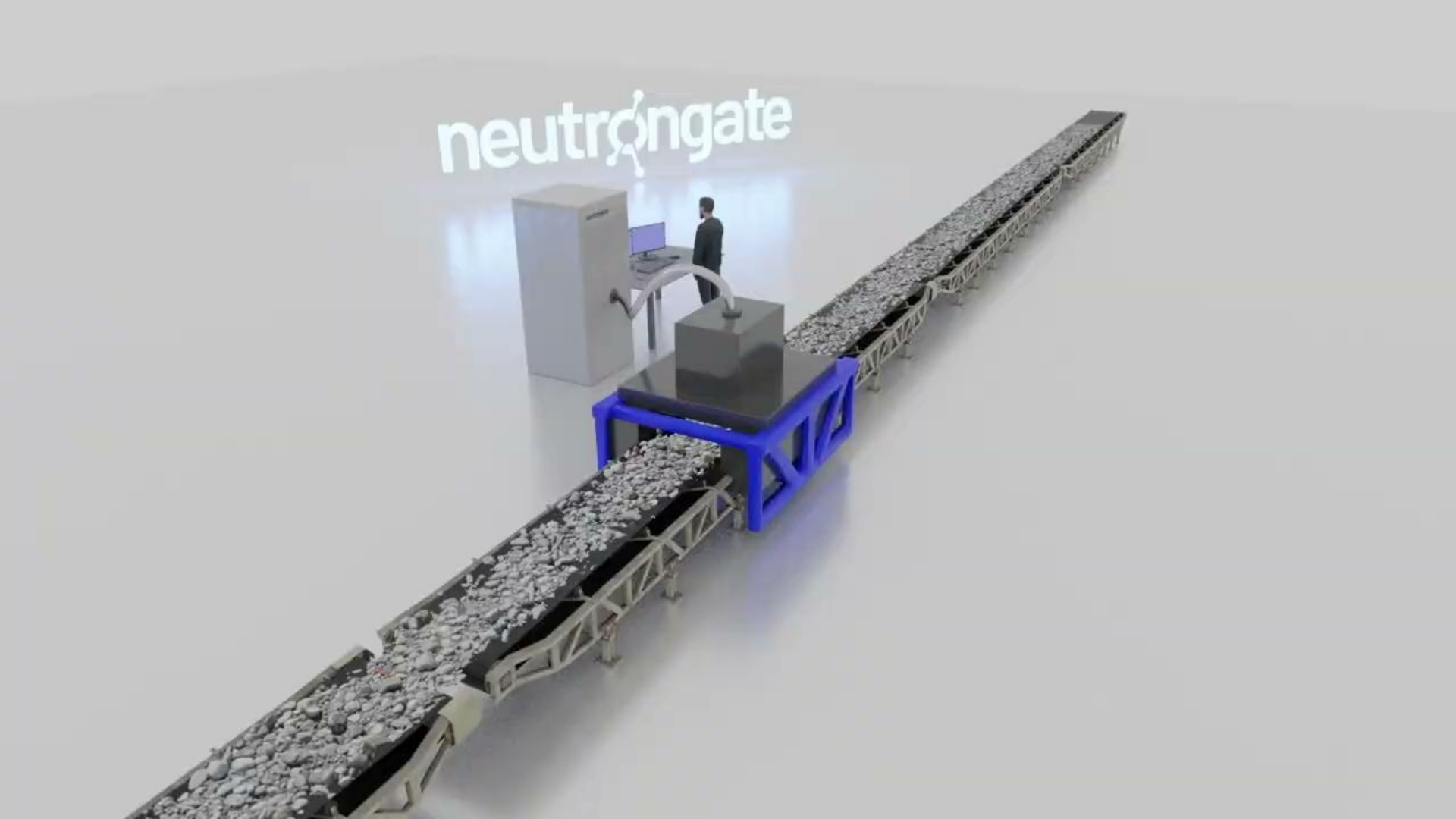
ELEMENTAL DATA
Raw data from detectors is filtered, calibrated and analysed providing elemental identification, elemental ratios and concentrations to the client.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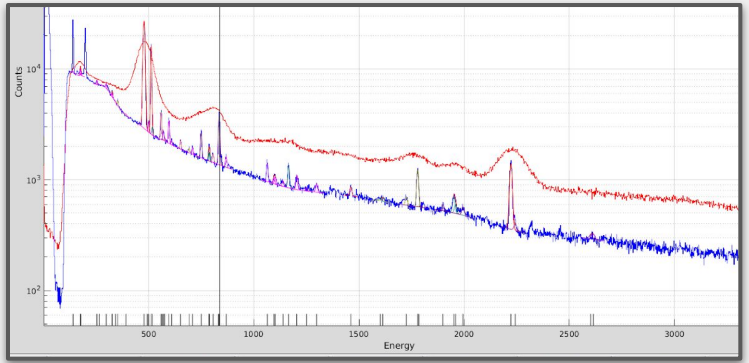
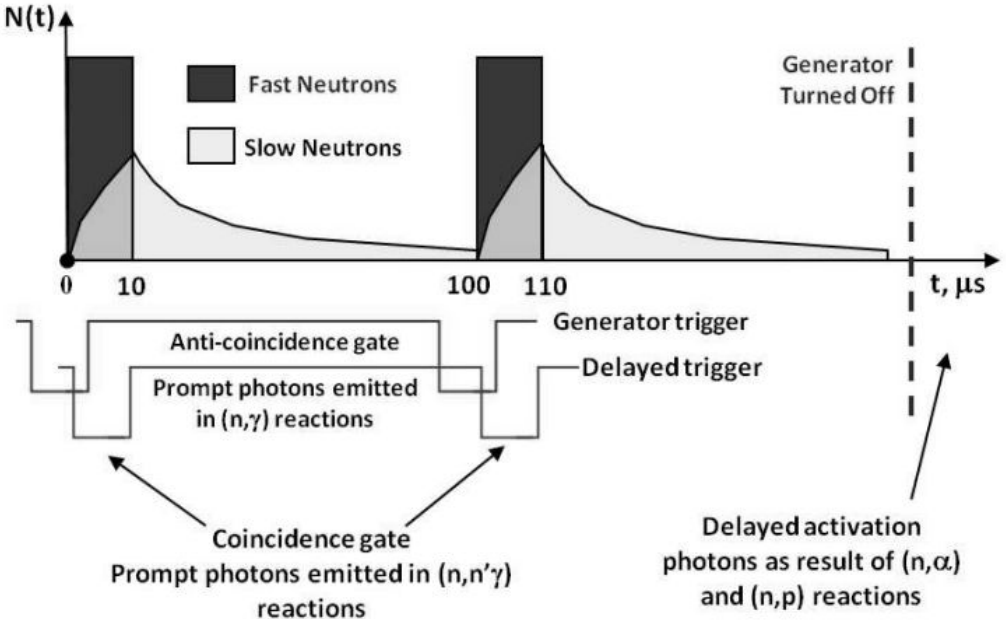
GAMMA RAY DETECTORS

Detectors used must tolerate high neutron flux

- BGO
  - Elements with low neutron capture cross-section
  - Great efficiency for high-energy gamma rays
- N-Type HPGe with TRP-preamp
  - N-type: Better resistance to neutron damage, can be annealed
  - TRP-pream for fast counting



PULSED FAST THERMAL NEUTRON ANALYSIS



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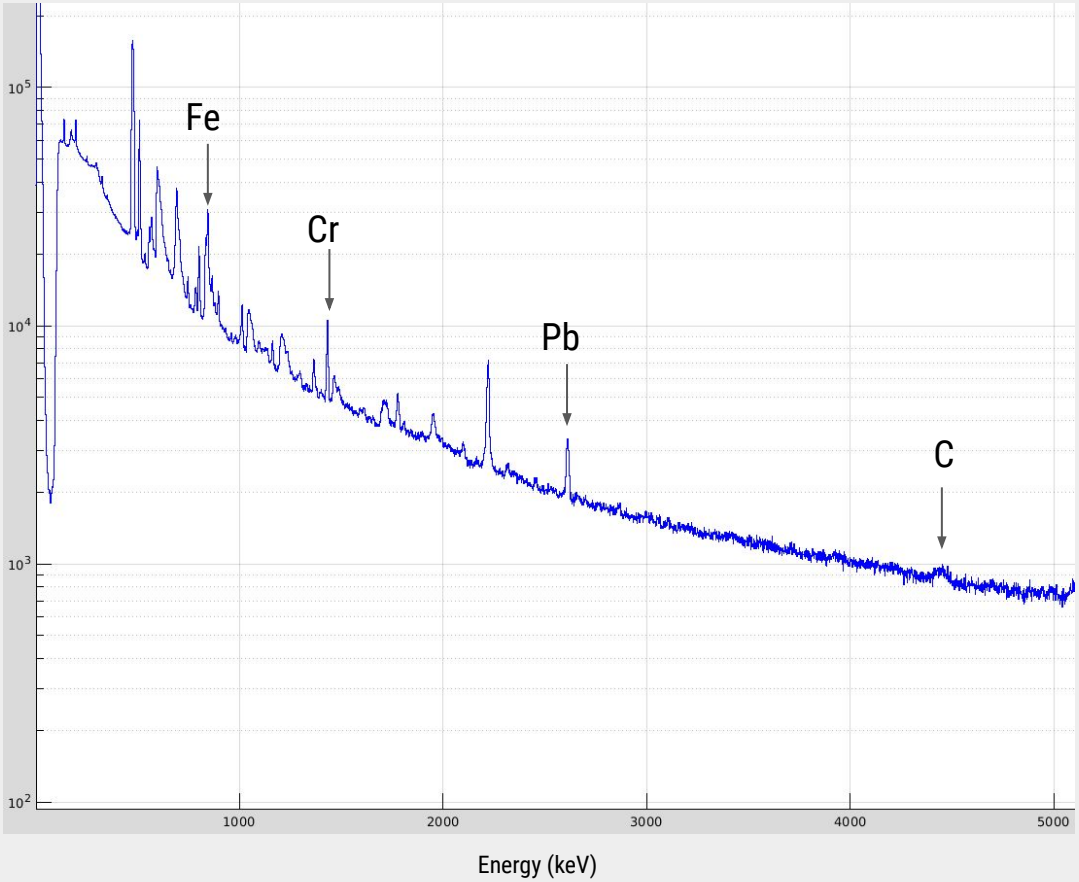
EXAMPLE: FAST NAA SPECTRUM



- Spectrum recorded during the neutron pulses
- Identified gamma lines induced by fast neutron recoil

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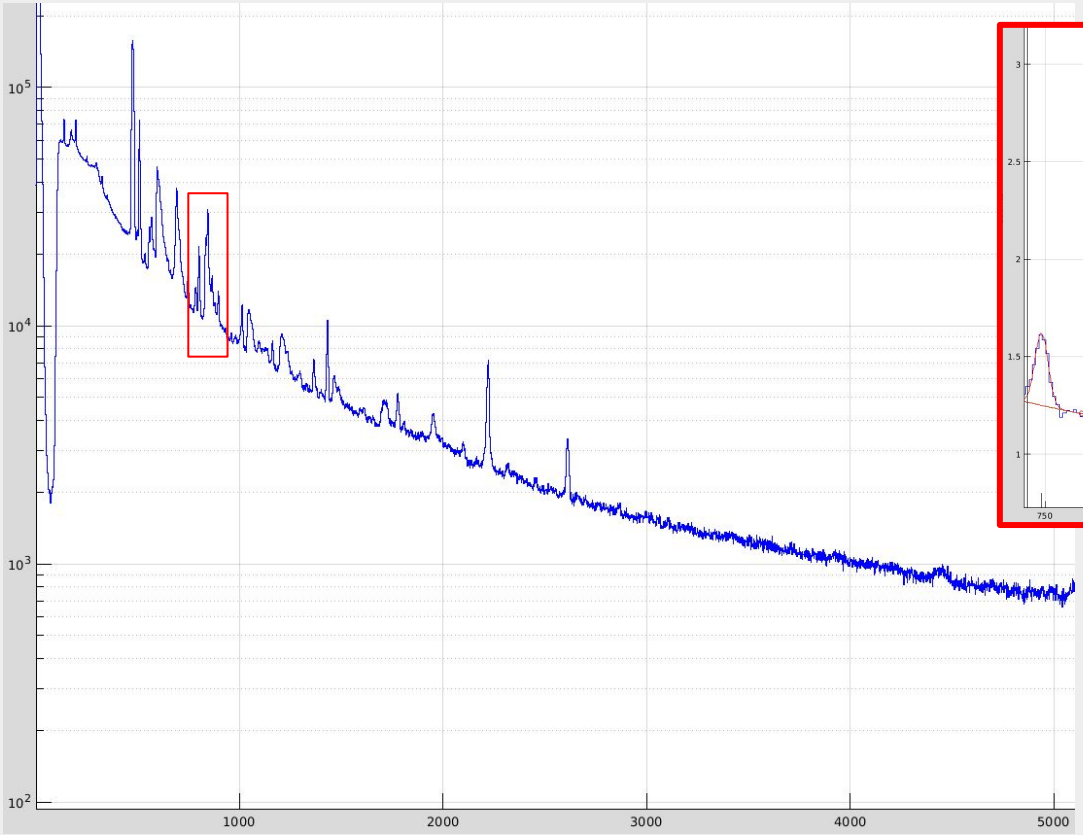
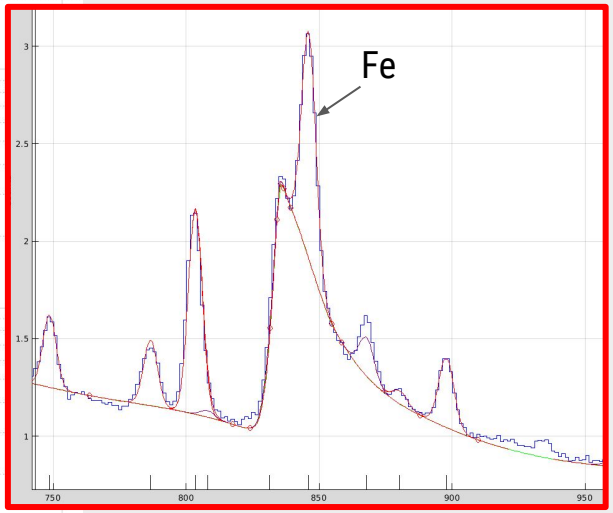
EXAMPLE: FAST NAA SPECTRUM





Shape model: T. Siiskonen, H. Toivonen;
A model for fitting peaks induced by fast neutrons in an HPGe detector, NIM A 540 (2005)

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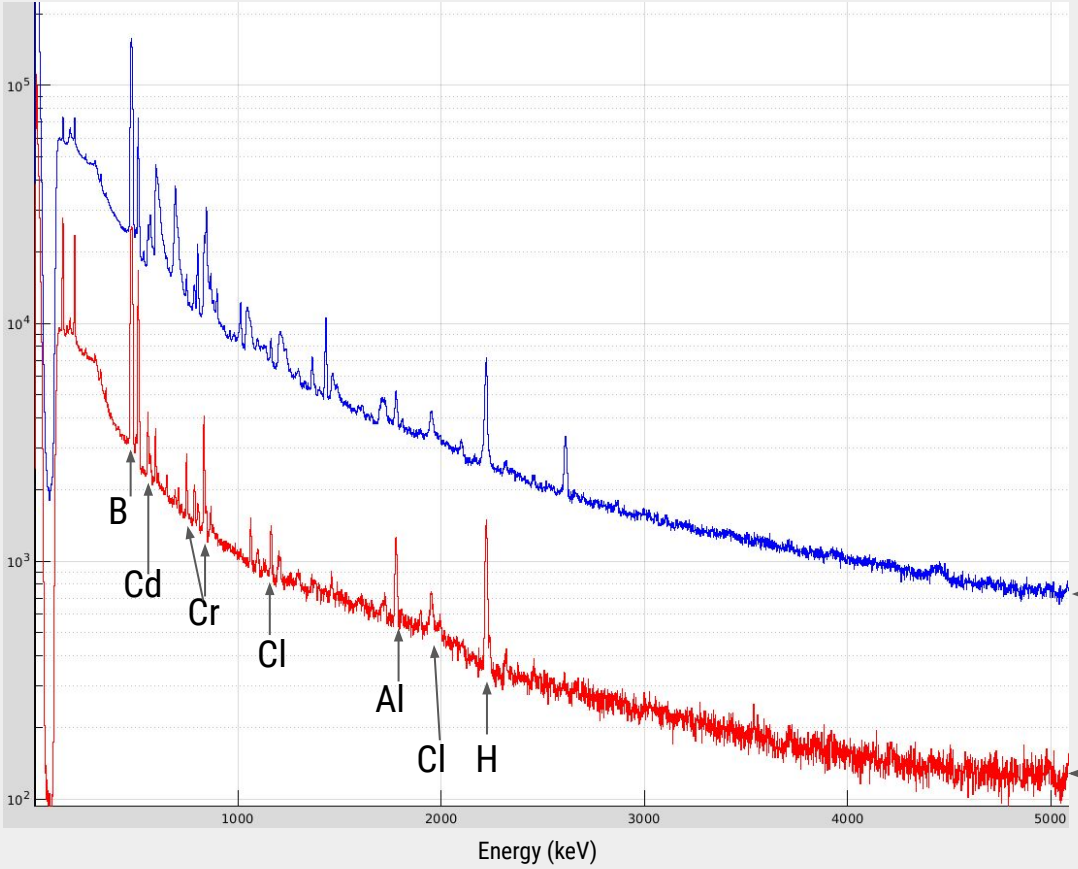
EXAMPLE: THERMAL NAA SPECTRUM



- Spectrum recorded between the neutron pulses
- Identified gamma lines induced by thermal neutron absorption

During the neutron pulses

Between the neutron pulses

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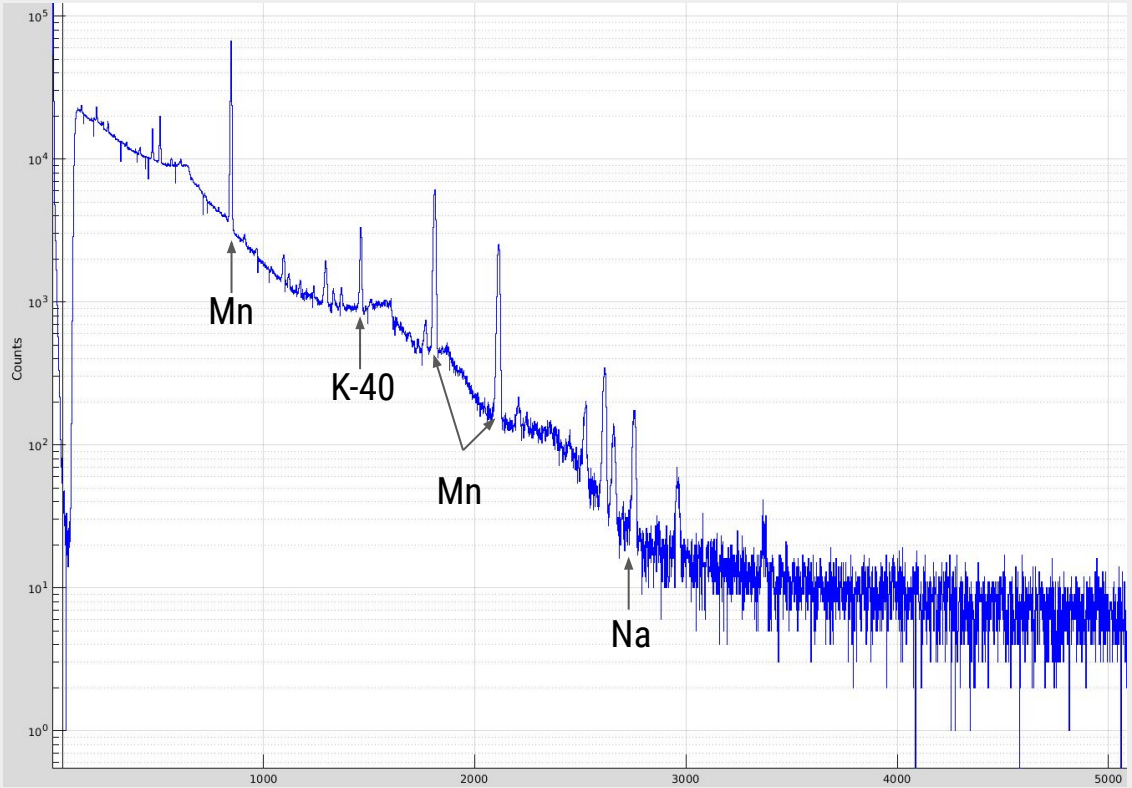
EXAMPLE: DELAYED NAA SPECTRUM



- Spectrum recorded after the neutron exposure
- Neutron activation products with long enough half-life
- Detector may not be exposed to neutrons

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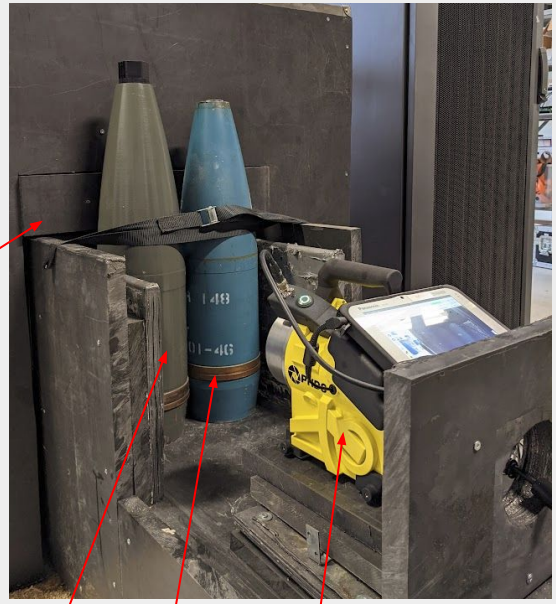
NEUTRON ACTIVATION GAMMA IMAGING



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HPGE REPAIR SERVICE

- Repair for HPGe detectors that are not under Manufacturer's Warranty
- Vacuum pump & bake
- Replacement of vacuum O-rings

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Thank You

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Detection thresholds for thermal PGNAA, DGNAA rough estimate

Detection threshold %-w	Element
<0.01	H,In,Au,Hg,Hf,Er,B,Cd,Nd,Sm,Eu,Gd,Dy
<0.1	Li,Na,Mg,Al,Si,S,K,Ca,Cr,Fe,Ni,Cu,Se,Br,Kr,Sr,Ru,Pd,Te,Xe,Cs,W,La,Tb,U, Cl,Sc,Ti,V,Mn,Co,Rh,Ag,Ta,Re,Pt,Ho,Yb,Lu
<1	Be,N,F,P,Ar,Zn,Ga,Ge,As,Rb,Y,Zr,Nb,Mo,Tc,Sn,Sb,I,Ba,Tl,Ce,Pr,Tm,Th,Np,Pu,Am
>1	C,O,Ne,Pb,Bi

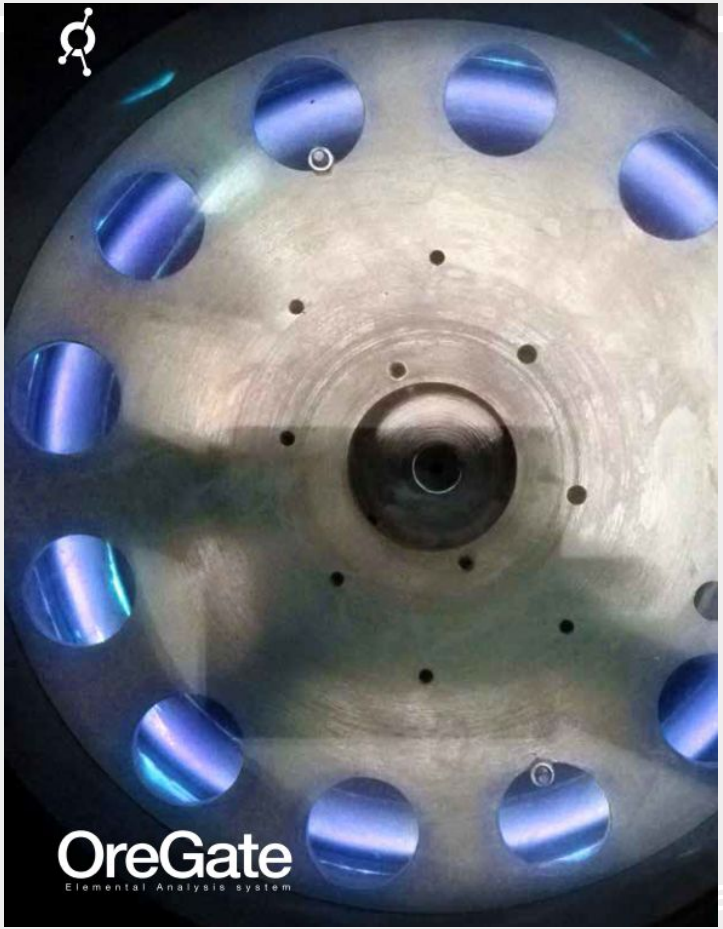
PGNAA detection thresholds.

Detection threshold %-w	Element
<1ppm	Mn,Rh,Ag,Hf,Sc,V,Kr,In,Eu,Dy
<10ppm	Na,Cu,Ga,As,Br,Sr,Y,Nb,La,W,Os,U,Sc,Sm,Ho,Lu,Re,Ir,Au,Al,I,Ba
<100ppm	Co,Ge,Ru,Pd,Sb,Te,Xe,Nd,Er,Yb,Pt,Hg,Ar,Mg,Mo,Cd,Pr,Gd,Ta
<0.1%	Ne,K,Ca,Ni,Rb,Tm,F,Cl,Ti,Zn,Se,Sn,Ce,Th

DGNAA detection thresholds, measurement time usually at least 10% of element half life.

When NAA is competitive

1. Large liquid and solid sample volumes.
2. In-line and real-time analysis is needed.
3. Surface- or sample analysis is not enough.
4. Representative analysis/sampling is needed.
5. Nondestructive or non-contact measurement is needed.
6. Element mass is important, regardless of material phase or chemical bonds.



AUXILIARY SYSTEMS:

Contain all the electronics and coolers in order to control and power the OreGate system. (Separate unit.)

NEUTRON SOURCE:

Electrical neutron source based on low energy particle accelerator producing neutrons via nuclear fusion reaction. Mainly via d(d,n)He, d(Li,n)Be fusion reactions. Advantages are safety, pulsed operation and high neutron yield.

RADIATION SHIELDING:

In OreGate configuration Radiation shielding surrounds the conveyor belt and patch is irradiated from top and gamma signal is detected from below or on top of the belt.

DETECTOR ARRAY:

Detector measuring the gamma radiation resulting from neutron irradiation. Detectors measure the energy spectrum which is characteristic to the elemental composition of material flow. Neutron detectors stabilize the neutron production.

OreGate
Elemental Analysis system

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