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12th International Beam Instrumentation Conference

An Experimental Setup for PIXE Analysis in a Medical Cyclotron at TENMAK-NUKEN

TU1C03

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Outline

- Motivation
- Experimental setup
- Measurements
- Outlook

Motivation

Analysis for

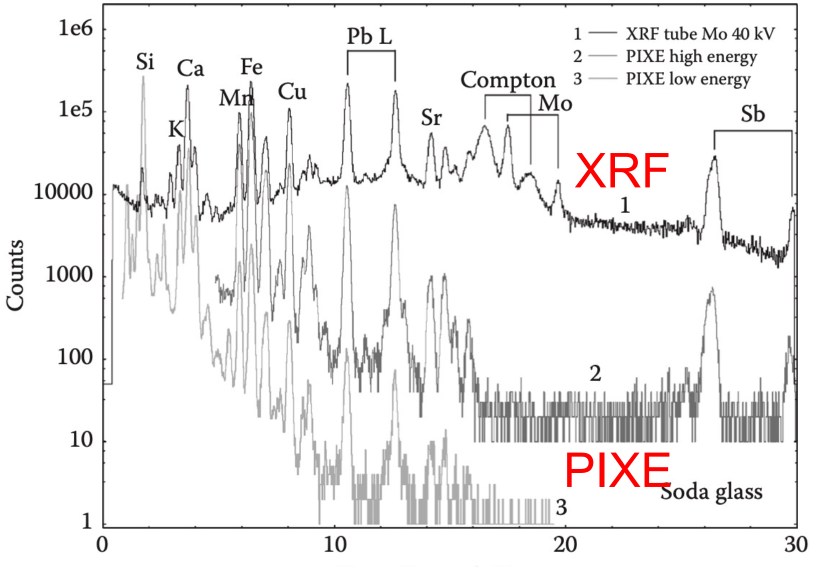
- Historical artifacts
- Forensic science
- Heritage science
- Semi-conductor technology
- Environmental science
- Minerals exploration
- Plant and animal biology
- Medicine, etc.

No facility in Türkiye for non-destructive IBA methods

Our country,

- 19 UNESCO World Heritage Sites
- cradle to a multitude of civilizations throughout history

IAEA
ACCELERATORS FOR HERITAGE



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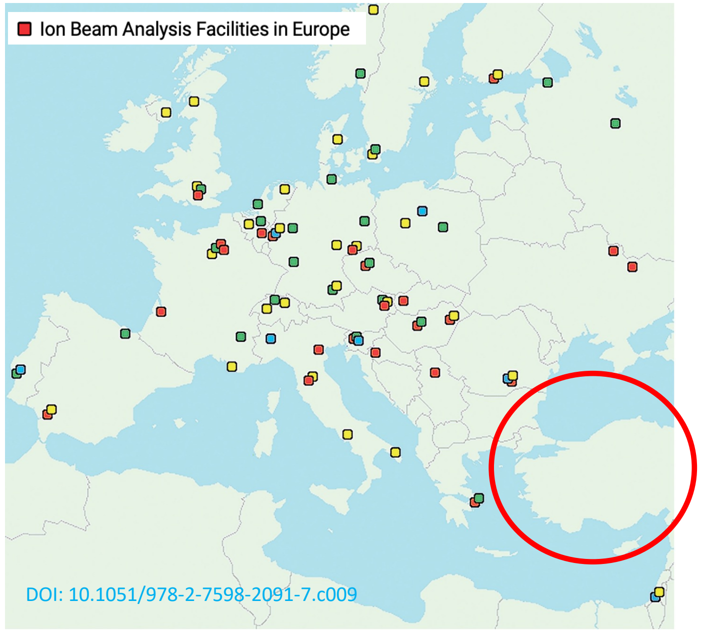

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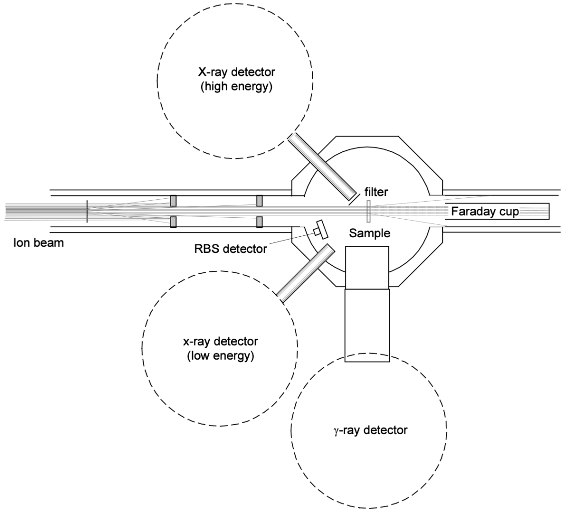


IAEA-TECDOC-1190

Proton Accelerator Facility

IBA S.A. proton cyclotron

15-30 MeV / 0.1-1.2 mA

4 irradiation vaults

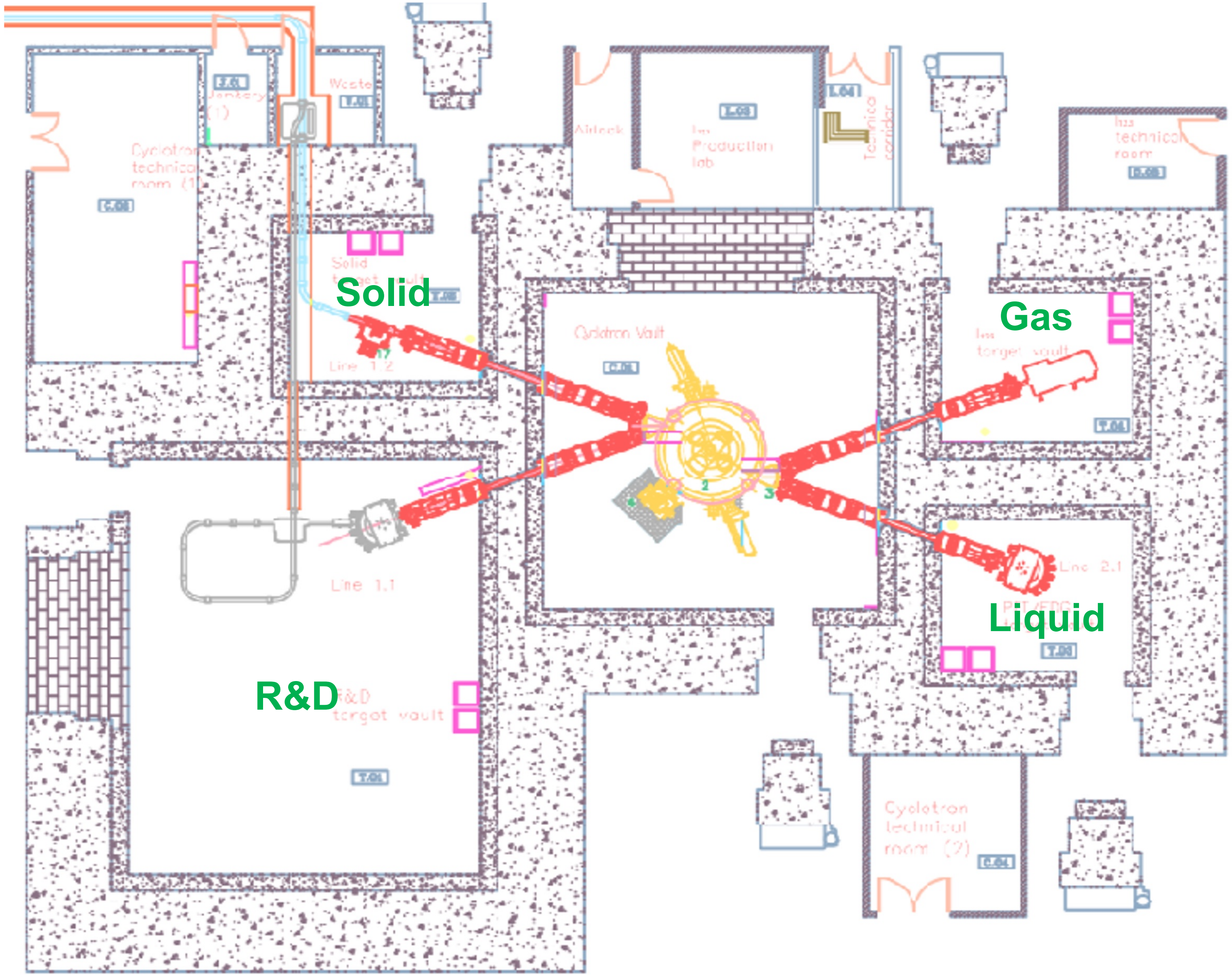
No. of personnel: ~30 (Phys., Chem., Biol., Eng., Tech.)

Radiopharmaceuticals/Radioisotope production (4 licenced products)

- NaI123, TlCl201 (active production)
- Ge68, Co57 (R&D phase)

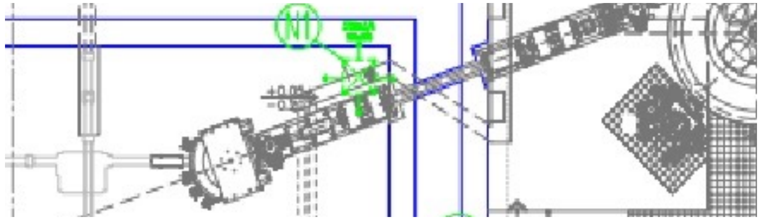
R&D studies

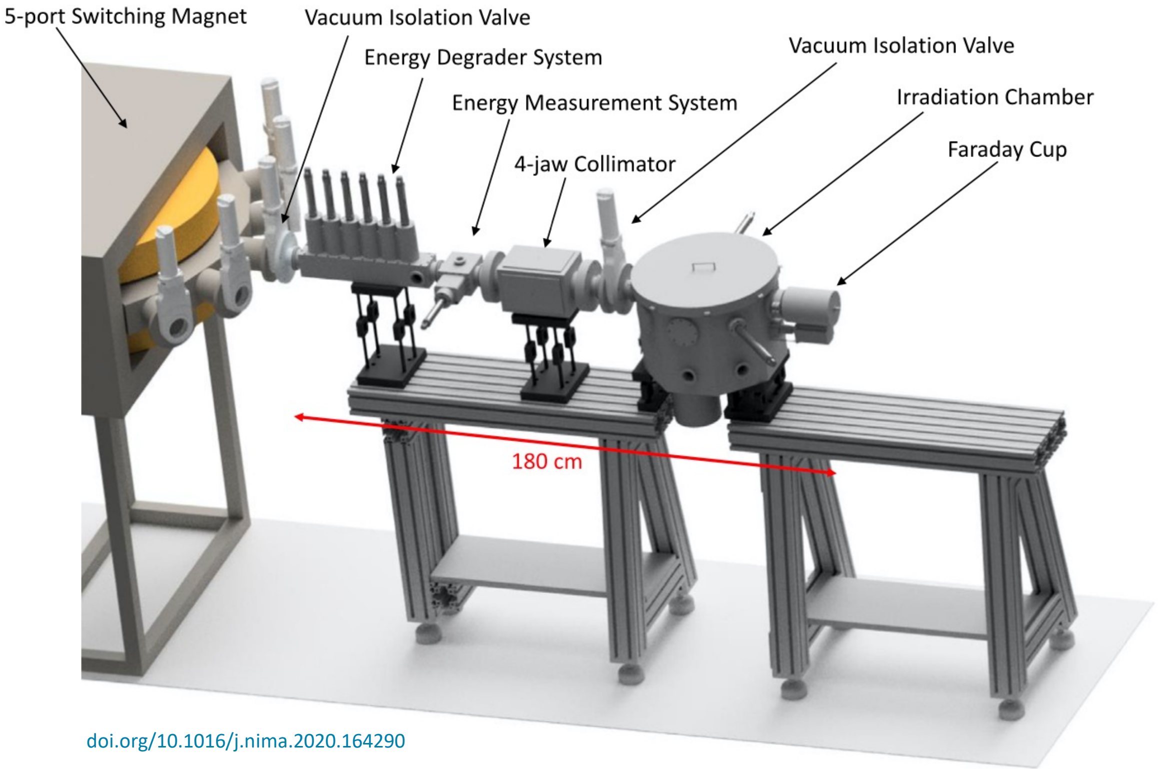
- radiation damage
- non-destructive analysis, etc.

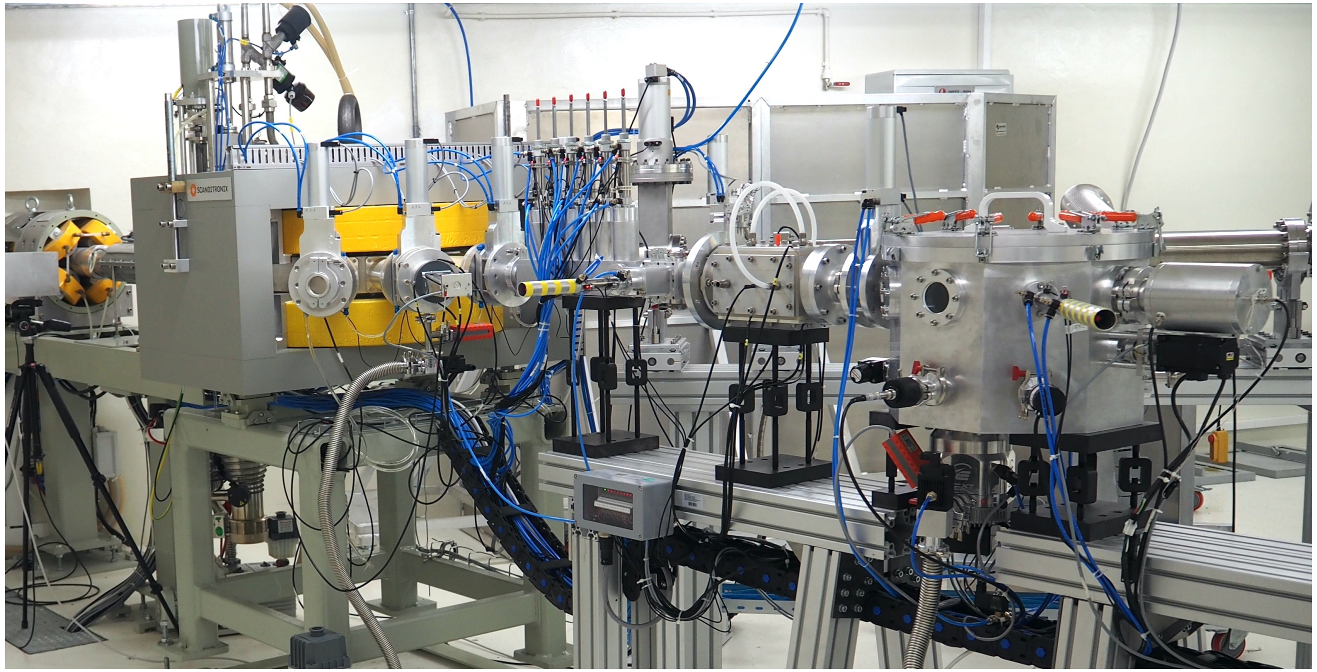


Irradiation setup

- Installed at the end of the R&D beamline (2 quadrupole doublets, 2 steerers, 4 FCs, 2 beam screens, 4-jaw collimator, etc.)
- Two different degrader systems (single and multi)
- In-vacuum and in-air irradiation capability
- 2-30 MeV, 5 pA-20 μA







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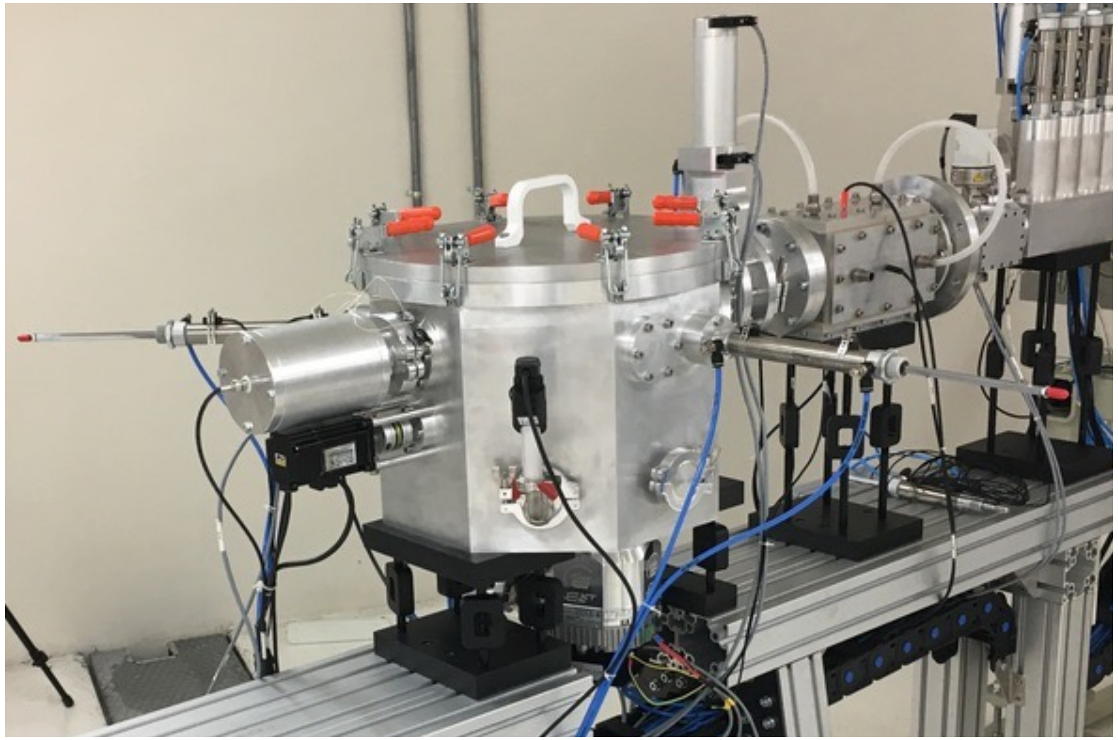
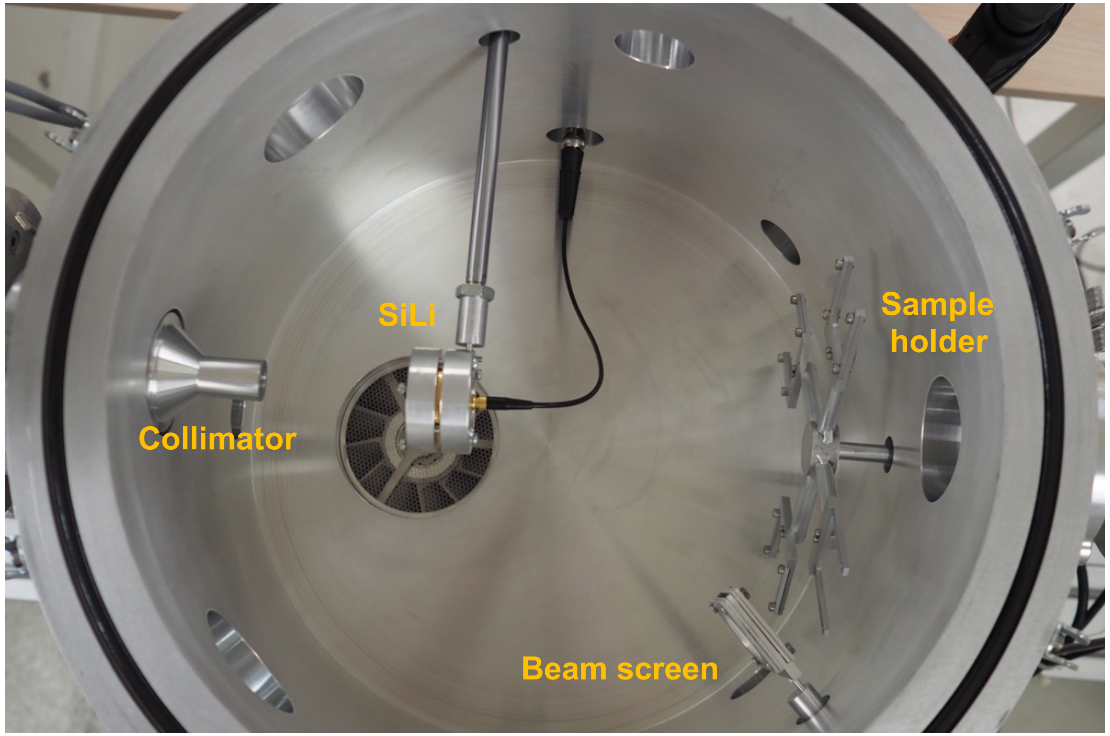
Irradiation chamber

- Octagonal shaped aluminum vacuum chamber
- 16 vacuum-tight ports
- 4 different samples can be irradiated in a single run by a servo motor
- Ports for PIXE, PIGE and RBS detectors and cabling





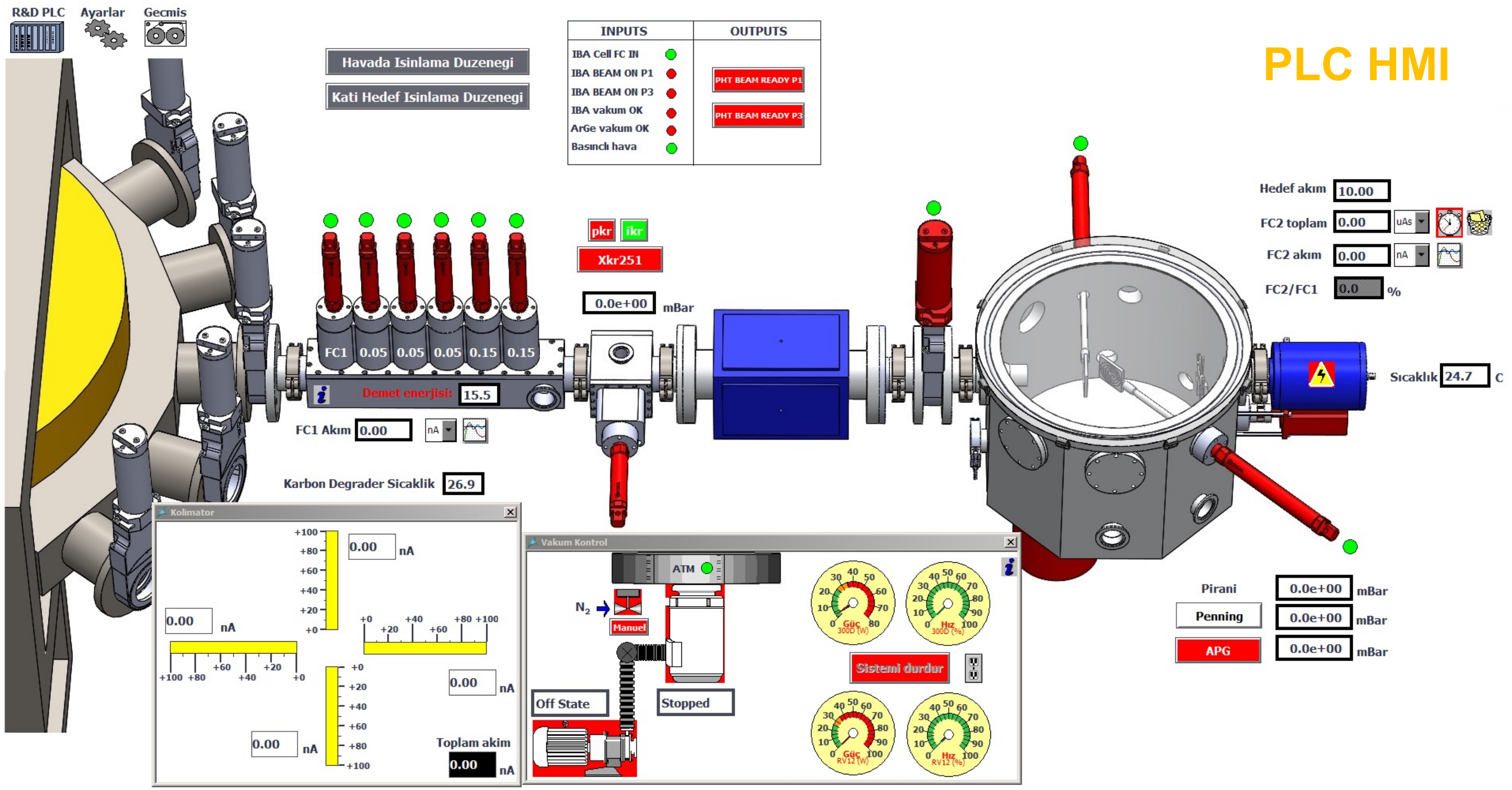
Control system & automation

Beamline equipment

- Degraders, detectors, screens (pneumatically) and sample holder (servo motor)
- Measurement and pumping systems

are controlled remotely by PLC.

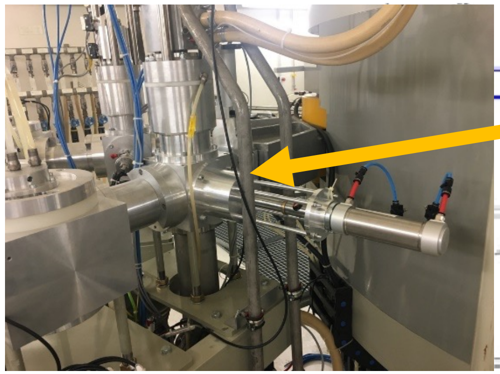
PLC HMI

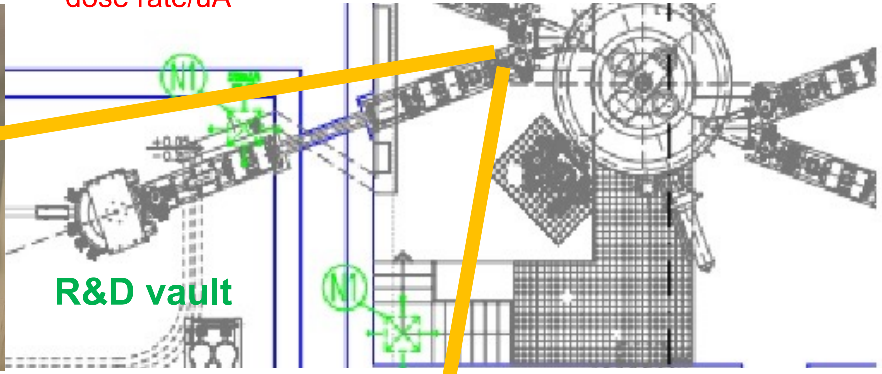


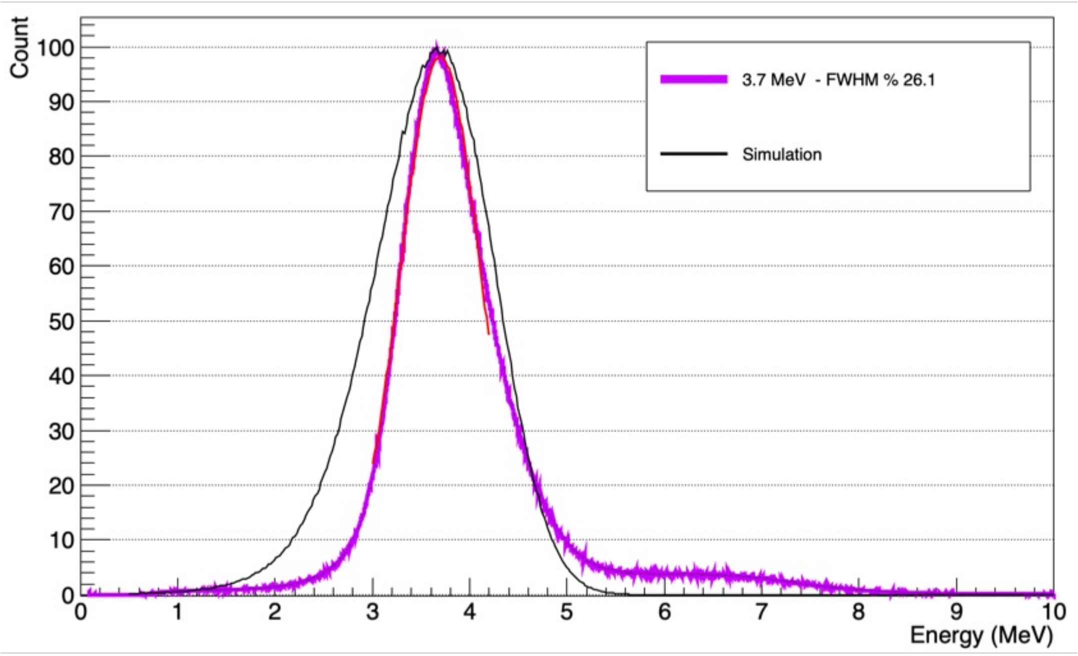
Energy degrader (single)

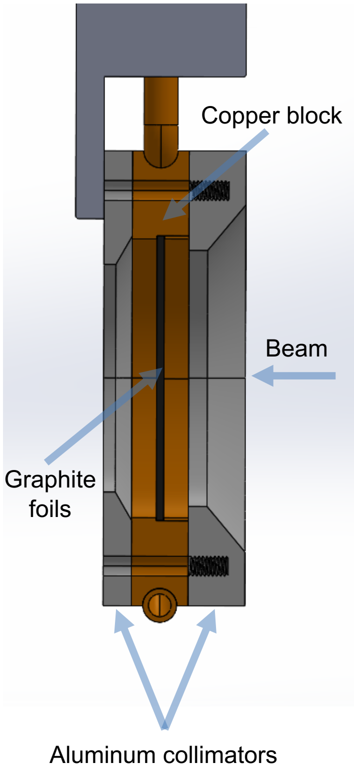
- Pyrolytic graphite foil set (total: 1.3 mm)
- Aluminum flanges for collimation (less radioactivity)
- Copper blocks for cooling (welded Cu pipe)
- Mounted on the FC box just after beam extraction
- Degradation down to 3 MeV is possible

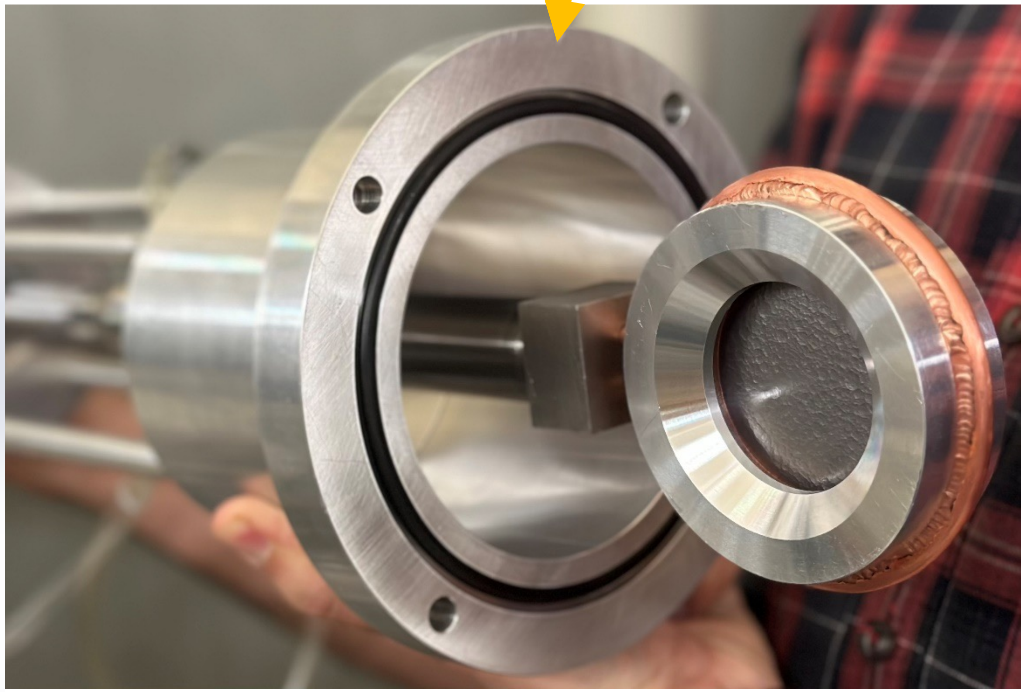
x550 reduction for gamma/neutron dose rate/uA











Energy degrader (multi)

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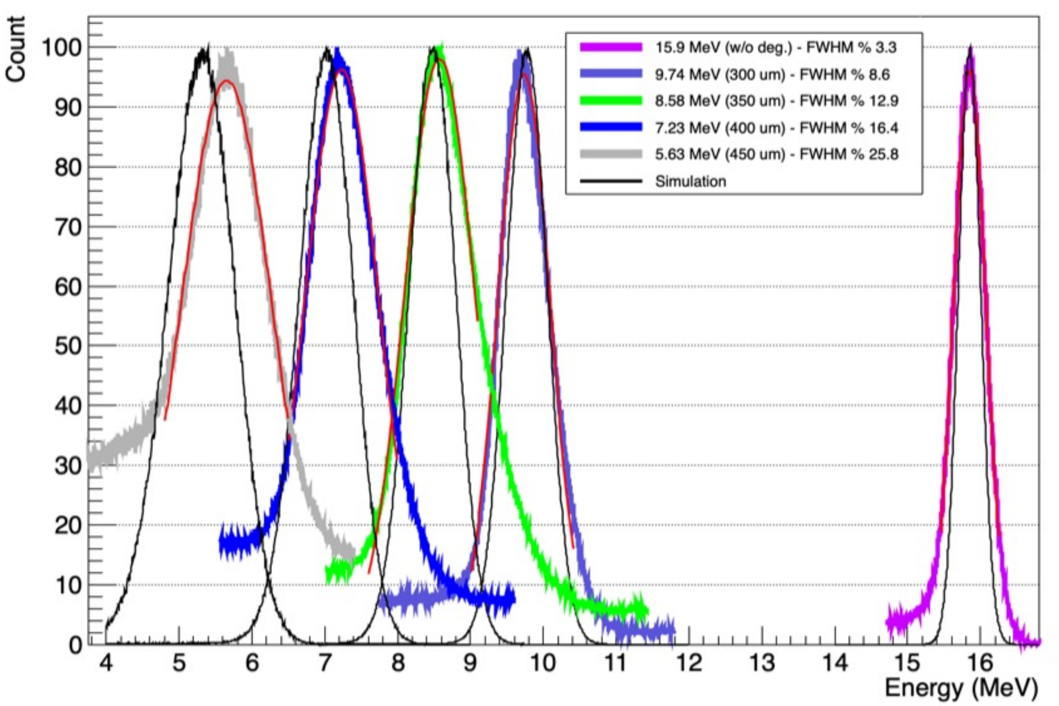
- Individually controlled copper degraders (maximum total thickness: 0.45 mm)
- Aluminum collimator (15 mm aperture) for each degrader foil
- Conduction cooling, no active component
- Inserted just after the 5-port magnet in the R&D vault
- Degradation down to 5 MeV



Beam energy measurement (SiLi)

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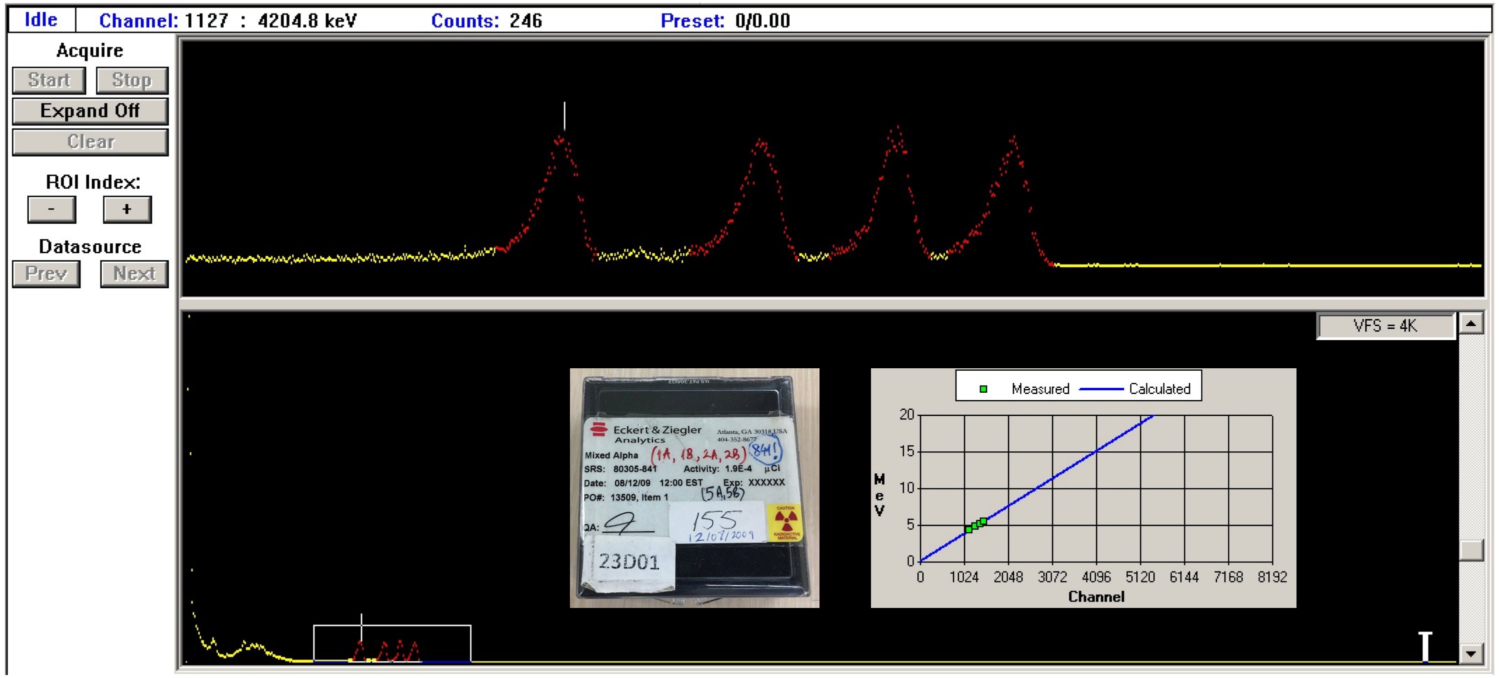
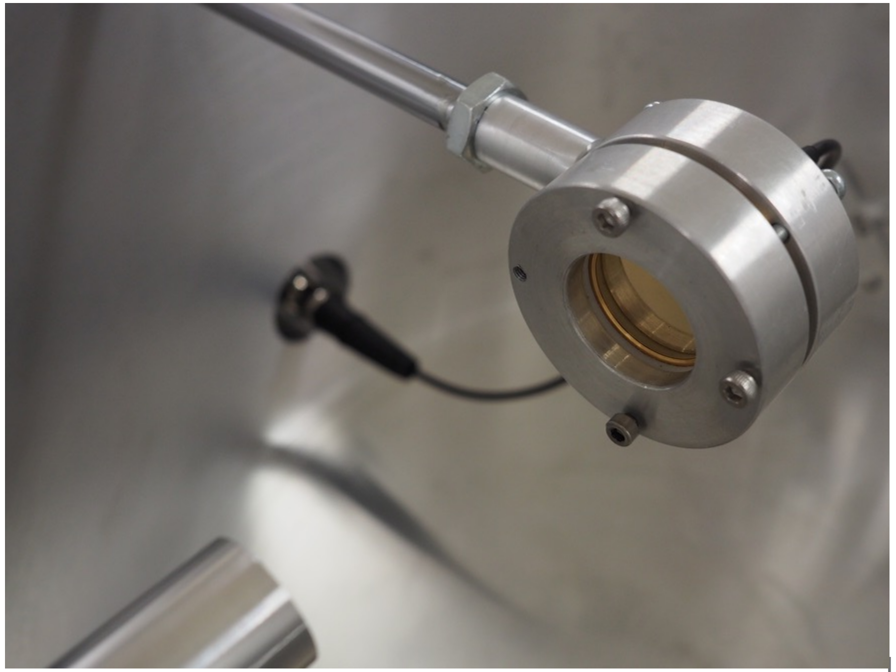
- Si(Li) detector with 5 mm thickness & 500 mm^2 active area, 55 keV FWHM
- Detects up to 30 MeV protons
- 2003BT Pre-amplifier & DSA-LX multi-channel analyzer & Genie software (Mirion)
- Calibrated with a multi-alpha source (4-6 MeV)





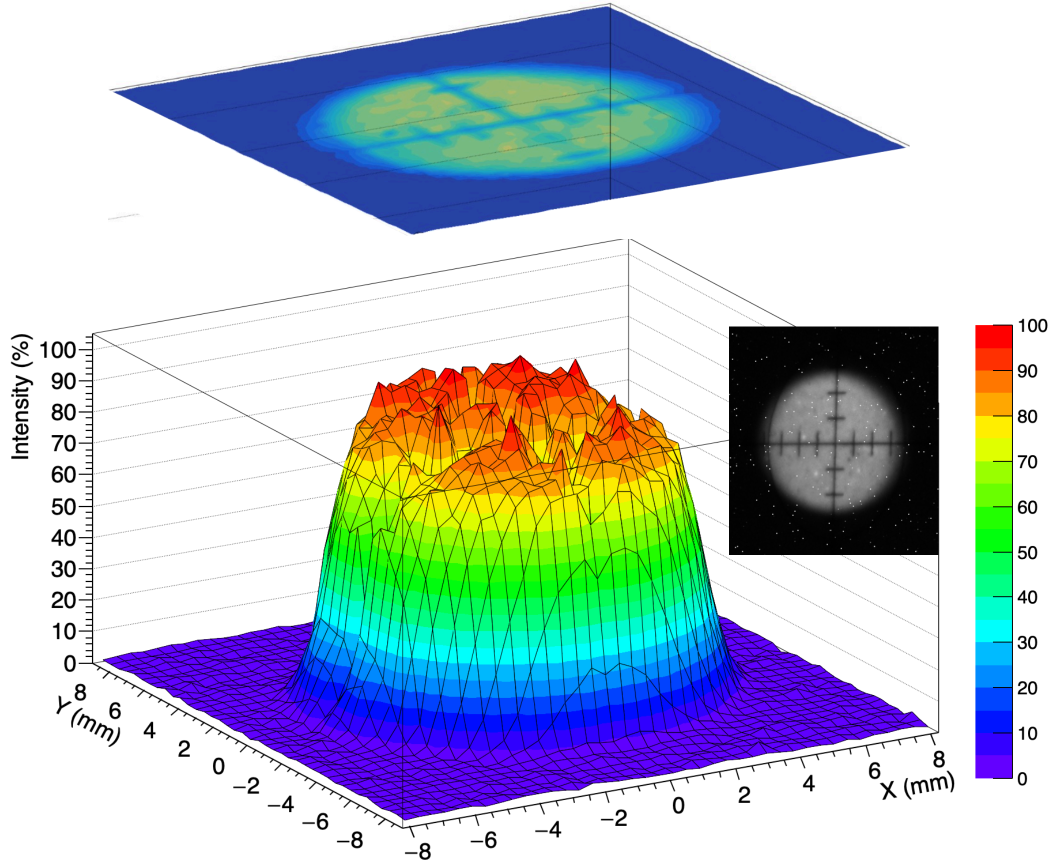
Beam size measurement

In-house produced Al_2O_3 screen (ϕ: 40 mm)

45° with the axis of the beam

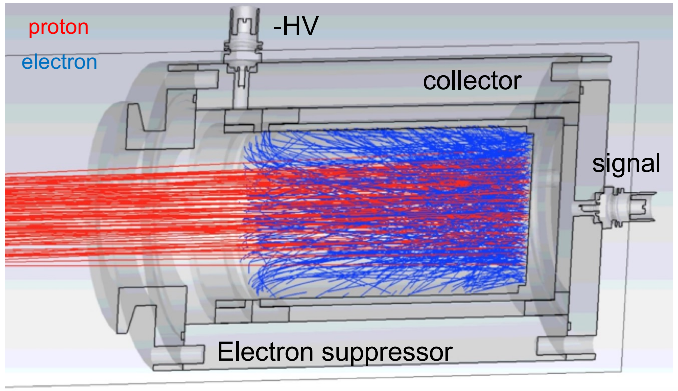
Beam is shaped with collimators with different sizes (1, 10 and 25 mm)

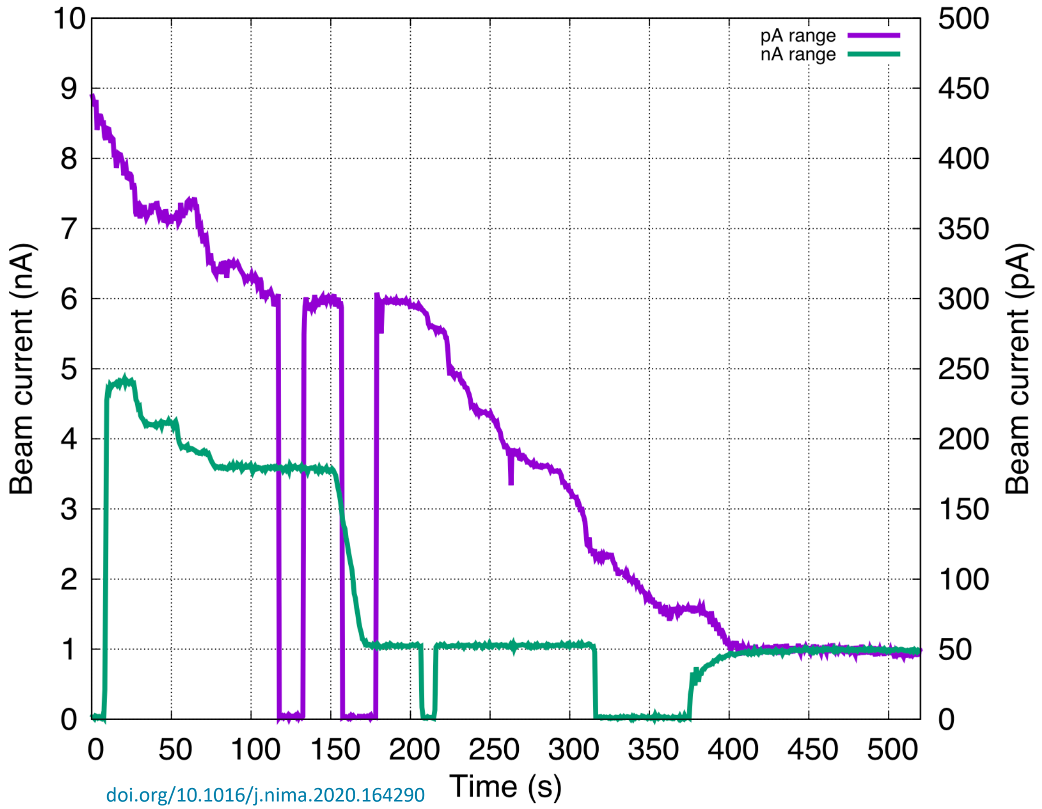
%90 intensity homogeneity (for 8 mm beam)



Current measurement

- 4-jaw collimator & 2 Faraday Cups
- 5 channel I-V converter with a microcontroller for collimator current
- Keithley 6482 Picoammeter for FC2 current
- Down to 5 pA and 10 pA SD at 1 nA’s.





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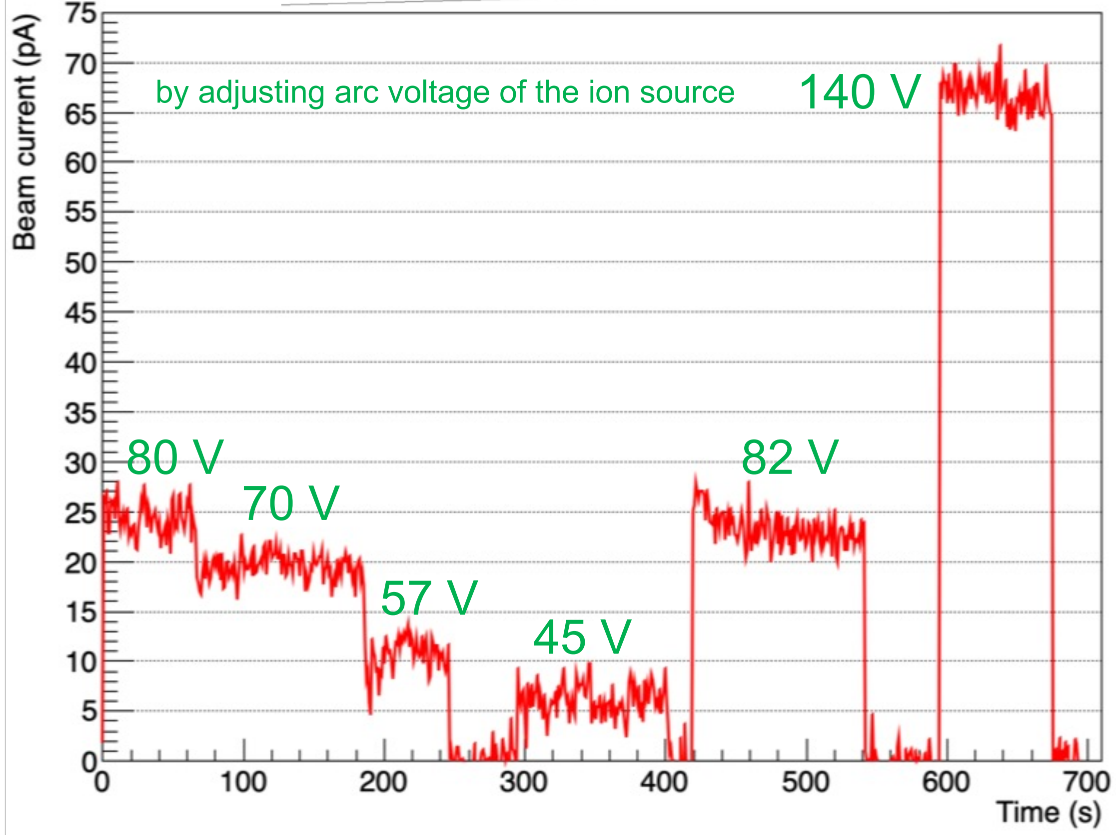
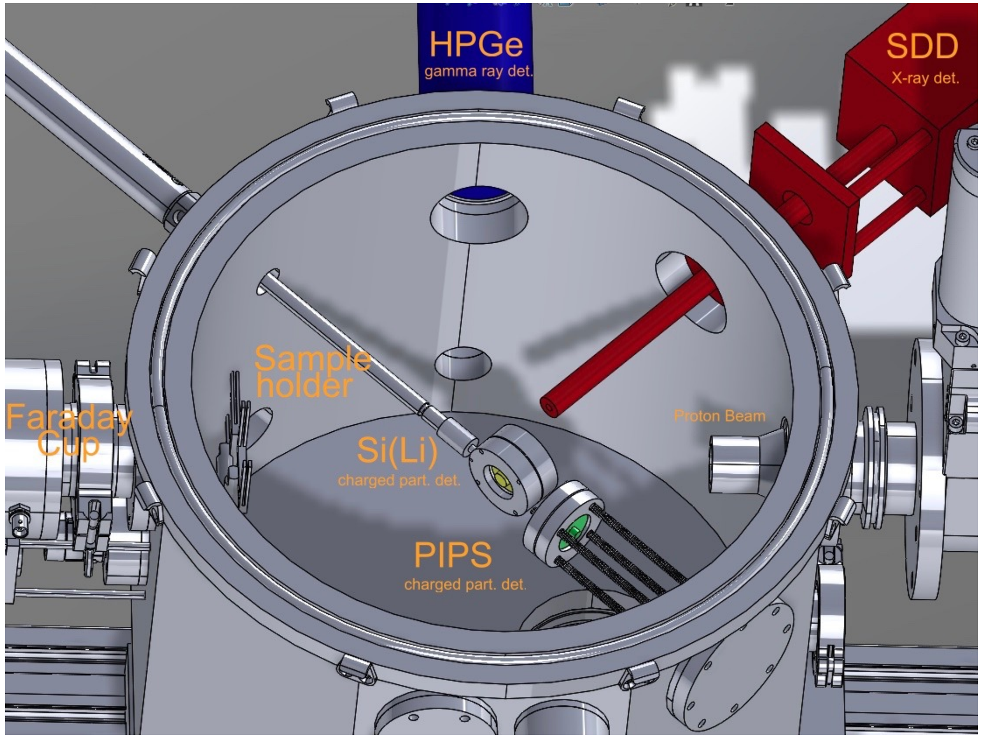
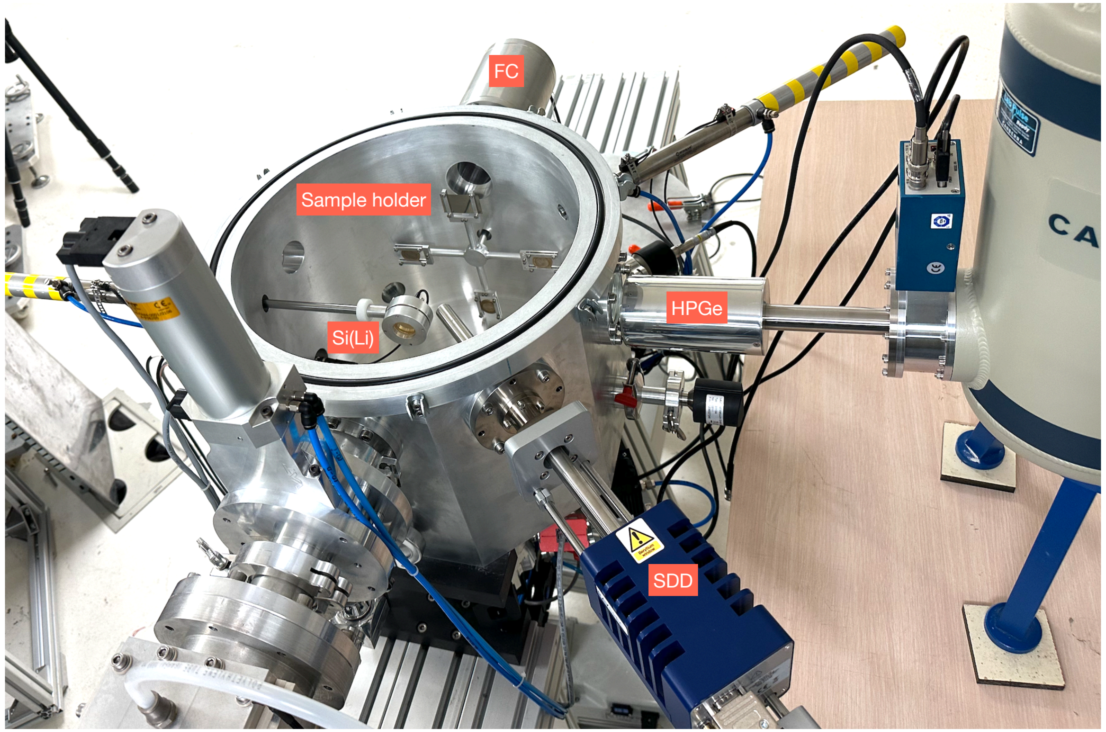


Irradiation setup for IBA analysis

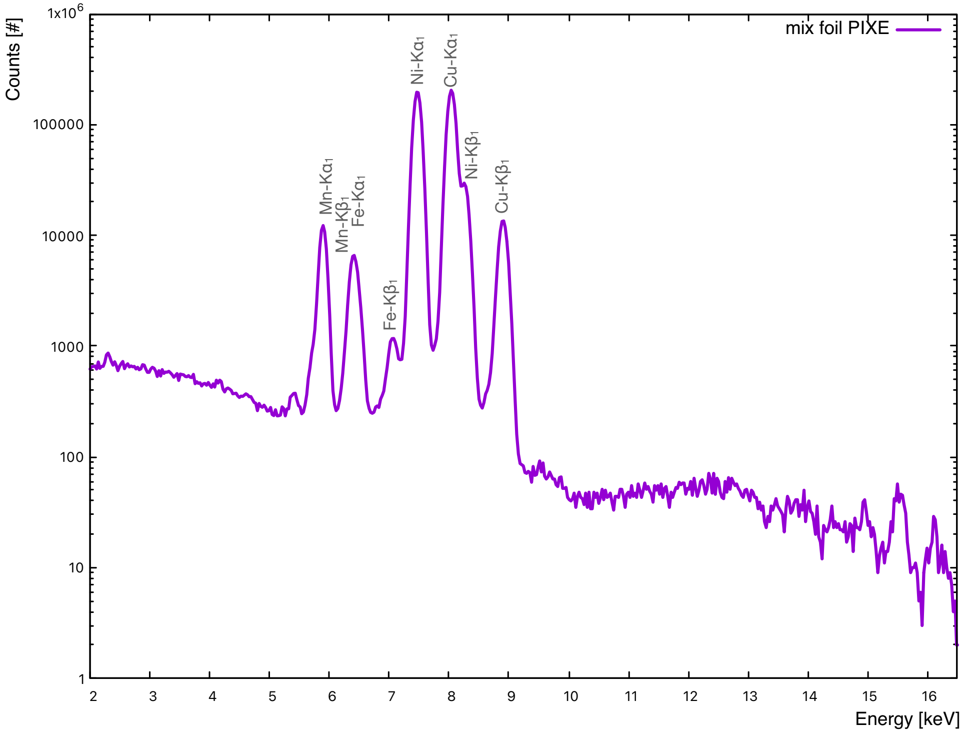
- SDD (Rayspec), 133 eV FWHM at 5.895 keV with 40 mm^2 active area and 8 µm Be window for **PIXE**
- HPGe n-type (Mirion), 2.1 keV FWHM at 1332 keV and % 30 relative efficiency with carbon-fiber endcap for **PIGE**
- PIPS (Ortec), 19 keV FWHM at 5.486 MeV with 150 mm^2 active area and 500 µm depletion depth for **RBS**
- Mirion and Ortec pre-amplifiers for signal management
- CAEN and Mirion MCA’s for digitization
- Quantus, Genie and GUPIX softwares for spectroscopy and analysis

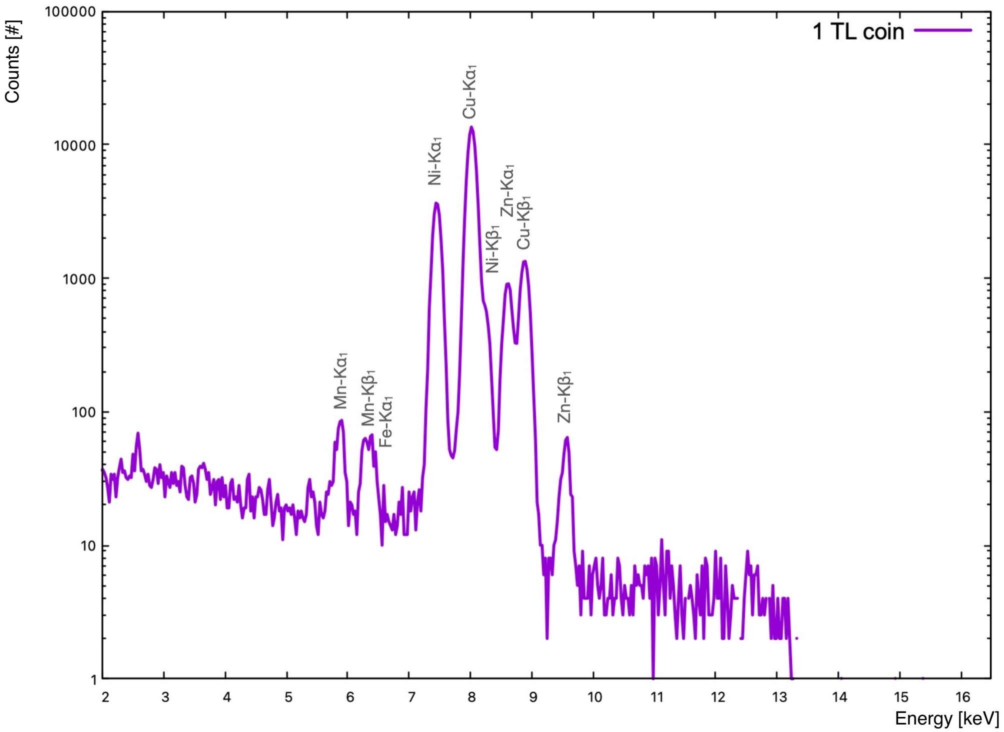




Preliminary PIXE analysis

3.2 MeV protons 7 nA current

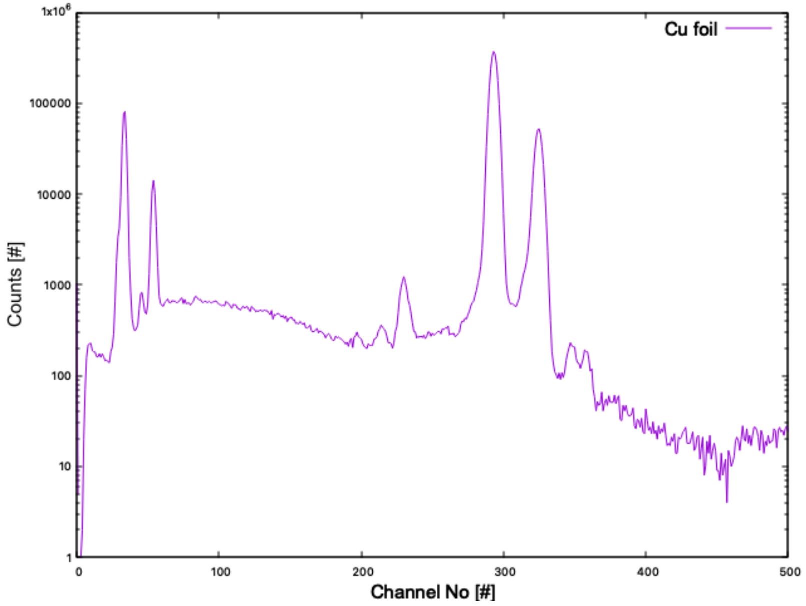


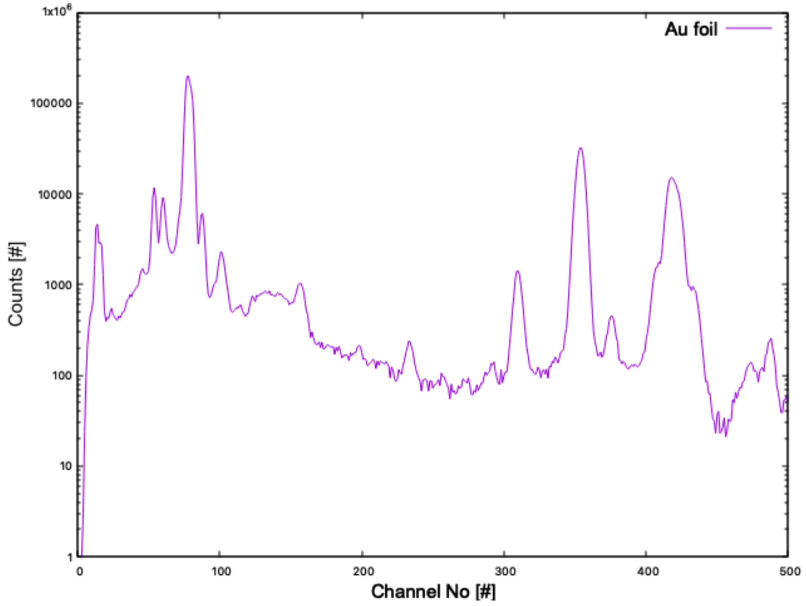


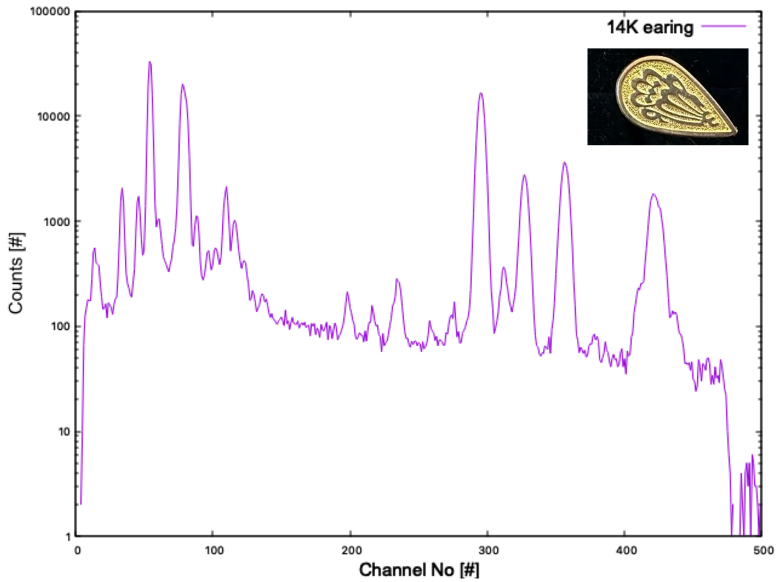
Element	XRF(%)	Unc.(∓)	PIXE(%)	Unc.(∓)
Copper	56.17	N.A	56.16	0.22
Nickel	41.66	N.A	41.95	0.17
Manganese	1.29	N.A	1.23	0.008
Iron	0.68	N.A	0.57	0.005

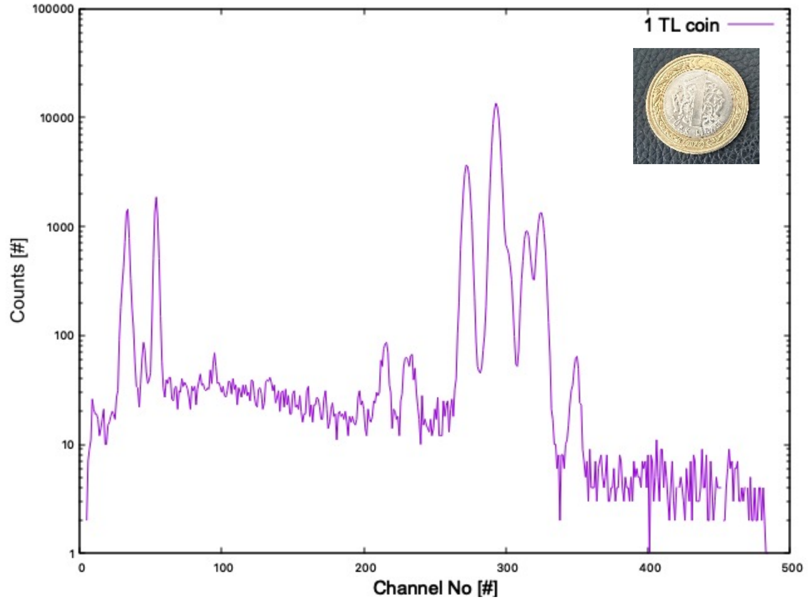
Element	1 TL(2009)		1 TL(2015)		1 TL(2022)	
	PIXE	XRF	PIXE	XRF	PIXE	XRF
	%		%		%	
Copper	73.2	71.78	71.22	70.56	76.70	72.63
Nickel	14.37	15.63	14.78	16.34	15.02	15.96
Zinc	9.12	9.53	8.74	9.13	8.57	8.50
Manganese	0.14	0.13	0.33	0.262	0.15	0.12
Iron	0.17	0.17	0.46	0.44	0.07	0.05

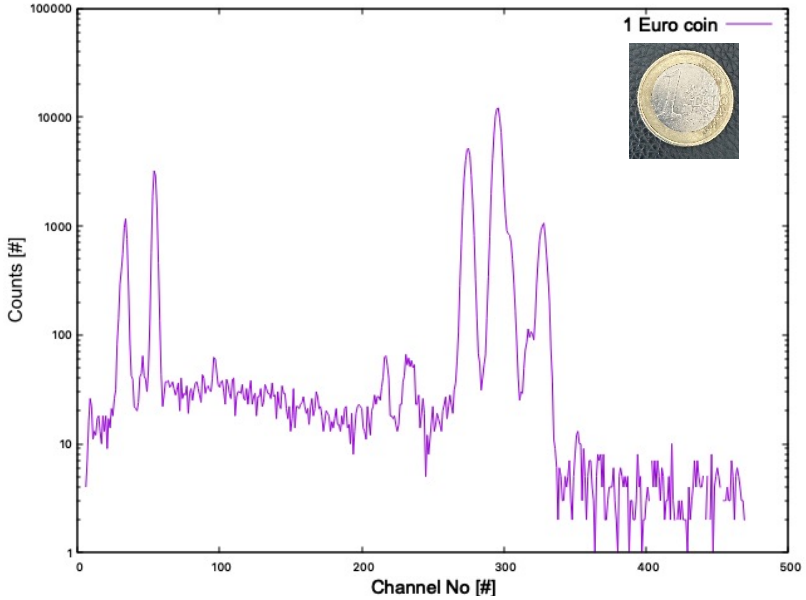
Preliminary PIXE experiments

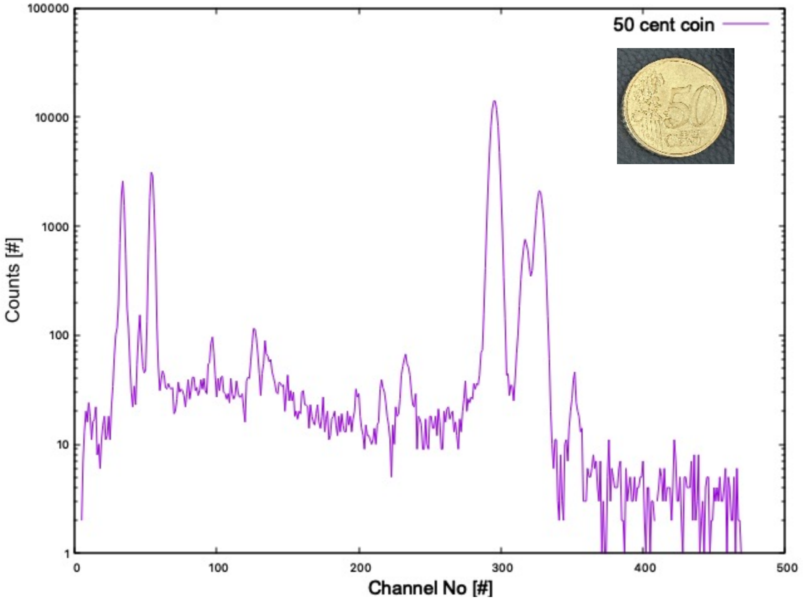




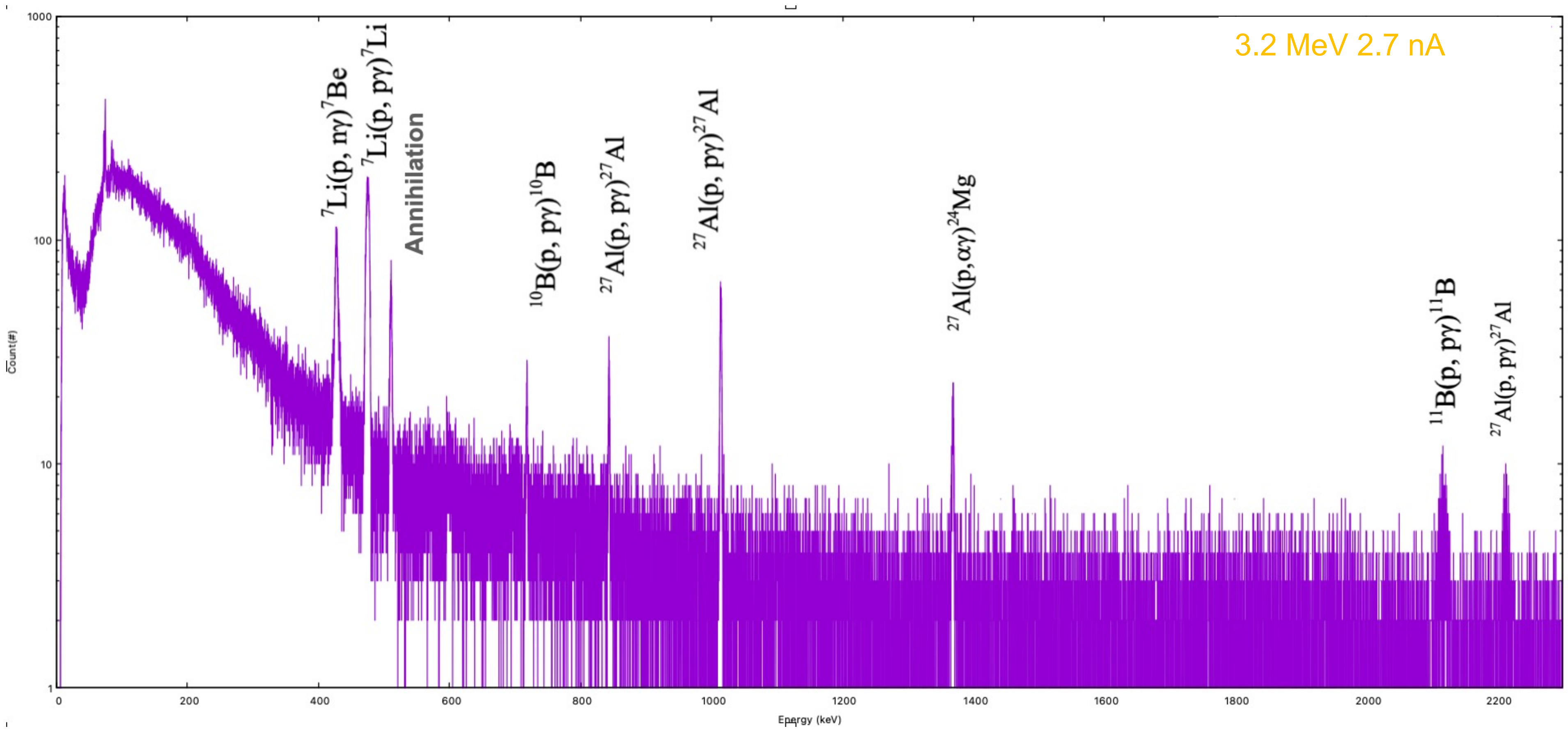








Lithium borate PIGE test spectrum



Planned modifications

Decreasing background:

- Putting an X-ray absorber/filter to suppress low energy X-rays
- Using detector collimators (low Z) to avoid scattered radiation
- Coating the inside of the chamber for decreasing secondary particles arriving on the detector
- Applying magnetic field to deflect scattered particles from the sample

Increasing precision of the analysis:

- More elaborate peak fitting procedures
- Detailed uncertainty budget calculations
- Developing a 3D sample movement apparatus

Decrease the energy spread:

- Moving the system to the 40° port of the 5-port magnet and let the beam passing through a slit
- Performing beam dynamics studies to determine the required magnetic field for the quadrupoles

Increasing the accuracy and precision of charge measurement

- Putting all components of the measurement system inside the vault

Outlook

- It is an ongoing work
- Planning to set-up a station for in-air PIXE
- Communication with national and international partners and stakeholders
- Standardizing the IBA methods
- Participating in proficiency tests and comparisons
- Providing ion beam analysis services

Ottoman archives


Göbeklitepe archeological site

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