JYFL Accelerator laboratory

Jyväskylän yliopiston kiihdytinlaboratorio - perustutkimusta ja uusia avauksia soveltavan säteilyfysiikan alalla

Ari Jokinen

- Accelerator Laboratory
- IGISOL
- Spectroscopy Group
- Underground laboratory – Pyhäsalmi mine
- Pelletron Laboratory
- RADiation Effects Facility
Accelerator laboratory

- Over 6000 beam-time hours a year
- Part of the Department of Physics
- Basic funding from Ministry of Education
- EU-Access Laboratory (ENSAR) 2011-2014
- Centre of Excellence (Academy of Finland) 2012-2017
- Accredited European Space Agency (ESA) test facility
- National Infrastructure Roadmap 2014-2020
Accelerated elements:
p – Xe
$E = \frac{Q^2}{A}$ 130 MeV

Ion sources:
6.4 GHz ECRIS
14 GHz ECRIS
Multicusp (H\(^{-}\), D\(^{-}\))

2014-2016 upgrade:
18 GHz ECR
**MCC30/15**

<table>
<thead>
<tr>
<th>Particle</th>
<th>Energy Range</th>
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<tbody>
<tr>
<td>H⁻</td>
<td>18 – 30 MeV</td>
</tr>
<tr>
<td>d⁻</td>
<td>9 – 15 MeV</td>
</tr>
<tr>
<td>beam current</td>
<td>200/62 µA</td>
</tr>
</tbody>
</table>

**Users:**
- IGISOL
- Radioisotope production

**New RF ion source**
- Intensity increase
- Continuous operation
K=30 MeV cyclotron

from K=130 MeV cyclotron

Off-line ion sources: (discharge, carbon cluster...)

Laser transport for optical manipulation/ ionization

IGISOL-4
The Next Generation

Laser ionization in-source/in-jet

Collinear laser spectroscopy

Decay spectroscopy (beam line not shown)

Mass spectrometry & post-trap spectroscopy

https://www.jyu.fi/fysiikka/en/research/accelerator/igisol
EXPERTISE:
- Production of rare beams, especially of refractory elements (Ion guide research, laser ionization)
- Decay spectroscopy of exotic isotopes
- Ion beam manipulation using optical and ion trap techniques
- Precision measurements applying Penning trap and laser spectroscopy
- R&D on research instrumentation
- Fission studies

PROJECTS:
- Fission yield studies (nuclear energy): p-, d- and n-induced fission of various targets
- Decay heat measurements (reactor technology)
- Proliferation (neutrino spectra determination through TAS measurements)
- Comprehensive Test Ban Treaty Organization (calibration of world-wide monitoring network)
- Material studies with implanted radiotracers (including refractory elements)
- Development of non-invasive analysis methods (neutrons)
Nuclear Spectroscopy Group

- Expertise in:
  - Gamma, Electron, Alpha Spectroscopy
- Detector technology:
  - Germanium (Composite, Planar, Co-Axial) Detectors
  - Silicon (DSSD, PIN-diodes, Application Specific) Detectors
- Data acquisition:
  - Digital and Analogue Pulse Processing
  - List-mode Data Acquisition (e.g. 500+ channels, triggerless, time-stamped, 10 kHz +/ channel)
  - Complex multi-parameter analysis of data from above
- Simulation (e.g. GEANT4, ion-optics,... )

Figure 4.5: An example drawing of simulated events visualised in Geant4. Electrons are presented with red lines and gamma rays with blue. Only some of the electrons reach the detector while the others either interact with the surrounding materials (open circles) or are reflected back by the HV barrier. Note also the magnetic bottle effect of electrons being trapped in the magnetic field.
Nuclear Spectroscopy Group

• Previous / Current Projects
• Themes:
  – Improvement of measurement techniques to lower MDA
  – Low-background counting
  – Exploitation of state-of-the-art detectors/electronics/data acquisition

Use of gamma-gamma coincidence technique to improve reliability and sensitivity in analysis of aerosol filters for verification of compliance with CTBT
Ongoing project: Use of state-of-the-art segmented germanium detectors and digital electronics/pulse shape processing to discriminate Compton background in full body / lung measurements (Pu, Am, etc) - P.Hallikainen (M.Sc thesis, JYFL 2014)
Also collaboration with University of Liverpool initiated
Finland has now a unique opportunity to establish

A world-class gamma-ray laboratory at the depth of 1400 m in the Pyhäsalmi mine

The scientific work in the mine (CUPP) should continue into the foreseeable future

Possible step-by-step approach to launch the low-background:

- Purchase of the first detector (e.g. LDM-1)
- Purchase of Ultra Low-Background Shield (e.g. CANBERRA 777)
- Dedicated cabin with additional shielding
- Dedicated cavern
- Multi-module setup
- Commercial activity?

29 October 2014

W.H. Trzaska
Main research fields

- Fundamental ion-matter interactions (cross sections, stopping forces, straggling)
- Ion beam analysis (IBA) for thin film samples
- Development of IBA techniques (detectors, data acquisition, simulations)
- Thin film processing (ALD, proton beam writing, irradiation)
- Materials research applications

Key facilities

- 1.7 MV Pelletron accelerator (in Jyväskylä since 2006)
  - Three ion sources, four beam lines
  - H, He, Cl, Cu, Br, I, and other heavy ion beams, 0.2 – 20 MeV
  - RBS, ToF-ERD, PIXE, and proton beam writing facilities
- Atomic layer deposition (ALD) tool for thin film research
- K130 cyclotron used for fundamental research and ion track production
Development of ion beam analysis techniques

- **ToF-ERD (Time-of-flight Elastic Recoil Detection)**
  - Quantitative depth profiling for all elements (H-Au), sensitivity < 0.1 at.%, depth resolution < 2 nm
  - Optimized timing gate design for improved energy resolution
  - Development of gas-ionization detector to improved mass separation
  - Digital data acquisition to improve high count rate performance and detection of low energy signals

- **PIXE (Particle Induced X-ray Emission)**
  - High sensitivity (ppm) for elements heavier than Al, no depth information
  - Superconductive transition edge sensor (TES) with 3 eV resolution @ 5.9 keV to observe chemical shifts

T. Sajavaara
External ion beam at JYFL Pelletron: Example of cultural heritage artefact studies

- RECENART – Research Center for Art established in Jyväskylä in 2014
  - Combines traditional and scientific methods to study art and artefacts
  - One of the analysis tools: External 3 MeV proton beam from 1.7 MV Pelletron accelerator used for particle induced x-ray emission (PIXE) measurements
  - Pilot study: Chinese bowl from Tang Dynasty (618–907 AD) period, composition of colors, glazing and body

PIXE spectrum from blue color shows high Cu content and the absence of Co: both typical findings for porcelain originating from Changsha kiln active during the Tang period

T. Sajavaara
RADEFE Facility

Official test laboratory of ESA since 2005
Ion cocktail 9.3·A MeV

<table>
<thead>
<tr>
<th>Ion$^q+$</th>
<th>E [MeV]</th>
<th>Range [μm]</th>
<th>LET @surface [MeV·cm²/mg]</th>
<th>LET @bragg [MeV·cm²/mg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{15}$N$^{4+}$</td>
<td>139</td>
<td>202</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>$^{20}$Ne$^{6+}$</td>
<td>186</td>
<td>146</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>$^{30}$Si$^{8+}$</td>
<td>278</td>
<td>130</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>$^{40}$Ar$^{12+}$</td>
<td>372</td>
<td>118</td>
<td>10</td>
<td>19</td>
</tr>
<tr>
<td>$^{56}$Fe$^{15+}$</td>
<td>523</td>
<td>97</td>
<td>19</td>
<td>21</td>
</tr>
<tr>
<td>$^{82}$Kr$^{22+}$</td>
<td>768</td>
<td>94</td>
<td>32</td>
<td>41</td>
</tr>
<tr>
<td>$^{131}$Xe$^{35+}$</td>
<td>1217</td>
<td>89</td>
<td>60</td>
<td>69</td>
</tr>
</tbody>
</table>

1. LET > 60 MeV/(mg/cm²)
2. Fast ion change with 7 ions
3. Bragg peak behind 50μm in silicon → this cocktail allows backside irradiation and do it also in air

**Note:** ECR type ion source and cyclotron type accelerator is the necessary combination
Existing projects:
- Energy loss measurement of protons in liquid water [1]
- This has been continued to energy-losses of $^{12}$C in water; data analysis in progress

Future plans:
- Varian Clinac from KYS installed in RADEF; ESA fund received for its commissioning
- Can be used to develop calibration methods of X-ray accelerators and related equipment
- Novel TOF method applied for other liquids and materials

New opportunities:
- New 15 MeV/nucleon beams for applications (e.g. Au –beam)
- Extend TOF experiments to include other tissue like materials
- Apply Clinac for studies of radiation effects in materials and tissue
Contacts:

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https://www.jyu.fi/fysiikka/en