Recent Achievements with VAMOS & EXOGAM spectrometers

Sugathan Pullanhiotan *
GANIL

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* on leave from IUAC, New Delhi
GOALS

Spectroscopy study of exotic nuclei
  Using different types of heavy ion reactions
  Low intensity Radioactive Ion beams

Advantages of VAMOS
  Large Acceptance
  Variable mode of operation
    Magnetic Spectrometer
    Recoil Separator

Coupling with other detector arrays
  EXOGAM
  INDRA
  TIARA
VAMOS capabilities

Collect Reaction Products with high Efficiency

Identify products by \( M, Z, Velocity \) - Selection of weak channels

Spectroscopy by Mass tagging - Clean gamma Spectra

Doppler correction using Velocity on event by event measurement

Measure reaction Yield and angular distribution
VAMOS Capability – A good example!
VAMOS Speciality:

**High acceptance spectrometer**
- Large Solid Angle
- High Selectivity for small cross section events

**Variable Mode operation**

Standard magnetic spectrometer (QQD)
- Elastic, inelastic, deep inelastic reactions
- Identification by Software Reconstruction of events
- Non zero degree operation to avoid beam and elastic counts

Recoil Separator (QQWFD)
- Reactions at zero degree
- Beam and residue having similar p/q but different E/q
- Residue separated by velocity set in Wien Filter
Momentum acceptance ± 5 %

Angular Acceptance

Horizontal = ± 100 mrad
Vertical = ± 160 mrad

Software reconstruction of events

Horizontal angle FWHM 0.5 degree
Vertical angle FWHM 0.9 degree
m/q resolution ~ 0.9 %

Path length 7.6 m
Rotation 0°-60°
Translation 0.4 - 1.2 m
VAMOS Detection & Identification

Hardware
Measurement of position, angle, dE, E & TOF

Software
Mass & Velocity reconstructed from measured parameters

Drift Chamber
X: charge distribution
Y: drift time

Ionisation Chamber

Secondary electron Detector

Silicon Wall

\[ x_1, y_1 \rightarrow x_2, y_2 \rightarrow \Delta E \]
Direct Measurement do not show features of mass spectra
VAMOS Particle Identification

\[ X_f \text{ and } Y_f \rightarrow \theta_f \rightarrow B \rho \rightarrow \theta \rightarrow M/q \rightarrow q \]

\[ M/q \sim B \rho \times \text{TOF} \]

\[ M \sim E \times \text{TOF}^2 \]

\[ Z^2 \sim E \times \Delta E \sim \Delta E/\text{TOF}^2 \]
Event Reconstruction Method

Drift Chambers give \( x_f, \theta_f, y_f, \phi_f \).

Reconstructed parameters are momentum and reaction angles at the target.

Co-ordinates at the focal plane mapped to the target coordinates by software reconstruction of events

\[
B = f_1(x_f, \theta_f, y_f, \phi_f)
\]
\[
\theta_i = f_2(x_f, \theta_f, y_f, \phi_f)
\]
\[
\phi_i = f_3(x_f, \theta_f, y_f, \phi_f)
\]
\[
Path = f_4(x_f, \theta_f, y_f, \phi_f)
\]

The mapping is based on higher order polynomial function

Coefficients derived from fitting of data using magnetic field map and ray tracing through spectrometer using transport code ZGOUBI.
RESULTS

Mass Spectrum

Velocity Spectrum

Mask image reconstructed at target
Experiments with VAMOS + EXOGAM
Gamma Spectroscopy of n-rich nuclei Using Deep inelastic Reaction

- Deep inelastic reactions
  - populate neutron rich nuclei
  - single particle and collective states
  - many nuclei at the same time

Beam $^{238}\text{U}$ @5.5 MeV/A, 2 pna current

$^{238}\text{U} + ^{48}\text{Ca}$

VAMOS at Grazing Angle 35 degree
EXOGAM with 11 clovers
Particles Identified from VAMOS event Reconstruction

Q = 20

Q = 18

$^{47\text{Ar}}$

$^{48\text{Ar}}$

Counts / 10 keV
Identification of neutron rich Ca isotopes

M. Rejmund et.al  to be published
More exotic nuclei!

Identification

One Si @ VAMOS fical plane
Elastic Scattering, Transfer near Coulomb energy

Reaction: $^{238}$U + $^{58}$Ni

- Spectrometer tuned for elastic Nickel recoils.
- Characterisation of Spectrometer to measure differential cross section
- Yield dependence on charge state distribution & angular distribution.
- Series of measurement at different magnetic settings.
- Geometrical acceptance of spectrometer.
Reconstructed mass spectrum for elastic & transfer products
Brho vs Scattering Angle

U + Ni --> Set for Nickel

U + Ca --> Set for Ca

E vs \theta
Acceptance Curve for the Spectrometer
The method of applying correction to derive relative yield is developed

Estimation of Yields to be completed

Measured charge state distribution
Summary

VAMOS coupled with EXOGAM makes powerful device for spectroscopy of exotic nuclei.

For first time seen gamma rays from exotic isotopes of Ar, Ca

Acceptance properties of spectrometer studied.

Methods to estimate reaction yields after acceptance correction is developed.
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Ionisation Chamber

Secondary electron Detector

Mylar emissive foil

Detectors based on Secondary Electron Detection

 Ionisation Chamber

Secondary electron Detector

Mylar emissive foil

Se-D

\[ X_{\text{FWHM}} \sim 1 \text{ mm} \]
\[ Y_{\text{FWHM}} \sim 2 \text{ mm} \]
\[ T_{\text{FWHM}} \sim 300 \text{ ps} \]