Activities of the Tandem Accelerator Lab in 2019

Anastasios Lagoyannis
Tandem Accelerator Laboratory
Institute of Nuclear and Particle Physics
N.C.S.R. “Demokritos”
Future (in 2018)

CALIBRA is coming…
  - Upgrade of the TANDEM
  - New ion - sources
  - New set – ups
  - Re-arrangement of existing ones
  - Upgrade of the electronics

Cross section measurements
  - Nuclear Astrophysics related
  - Light elements deuteron induced reactions
  - Proton induced gamma – ray reactions

Applications
  - micro – beam carbon quantification in JET samples
  - Collaboration with INN
  - Proton – tagged PIGE
SP2: Unseal the offer(s) on 15/11

SP3: Technical offer unsealed on 13/11

SP4: Tender finished. Contract signed. Delivery in February 2020

SP5: Depends on SP3

SP6: Technical offer(s) unsealed on 11/10

SP7: Tender was announced on 13/11
Tandem Layout

- Charged-particle induced X rays
- μ-PIXE
- γ-calorimetry
- RBS, NRA, ERDA...
- γ-spectrometry
- multipurpose scattering chamber
- d-filled gas-cell
- Tritiated Ti target (rotating)
- Auger Spectrom.
- γ-spectrometry
- charged-part. irradiations
- neutron irradiations

A. Lagoyannis
I.N.P.P. Annual Meeting
Thursday 14/11/19
Tandem Upgrades – SP2

Tandem hall

5.5 MV Tandem Accelerator

Conversion to PELLETRON
Replacement of existing belt

TORVIS multicusp ion source

Conversion to Pelletron already performed at the “sister” 5.5 MV Tandem accelerator of Athens, Ohio, USA

SNICS Sputter source

Full remote control of the accelerator via PC (AccelNET system)

All accelerator components on a screen
Tandem Upgrades

The R +15 beamline

Beam line extended – “Neoptolemos” transferred
The R +60 beamline  GASPAR (electronics @ SP4)
Nuclear Astrophysics Cross-Section Measurements

**p-nuclei**
35 neutron deficient nuclei between $^{74}\text{Se}$ and $^{196}\text{Hg}$

**p-process**
Network of more than 20000 reactions ($\gamma$,n), ($\gamma$,p), ($\gamma$,a), n-, p-, $\alpha$-captures, $\beta$-decays, e-captures
⇒ a huge number of cross sections have to be known

**HAUSER-FESHBACK THEORY**
Several models of the nuclear ingredients (OMP, NLD, ...) in the HF calculations

The $4\pi$ summing method

Angular Distributions

\[ \sigma = (\gamma/\varepsilon)^* (1/\varepsilon)^* (A/N_A) \]

**BUT!!!**
Efficiency $e = f(M,E)$

\[ W(\theta) = A_0 + a_2 P_2(\cos \theta) + a_4 P_4(\cos \theta) \]

\[ \sigma = \frac{A}{N_A N_p \varepsilon} \sum_j A_{0,j} \]
Simulated Efficiency for $4\pi$ Summing Method

$\sum E = \gamma_1 + \gamma_2 = 2505.7$ keV

$^{137}$Cs

$\langle M \rangle = 3.2$

$^{27}$Al(p,γ)$^{28}$Si

A. Lagoyannis
I.N.P.P. Annual Meeting
Thursday 14/11/19
Differential Cross Section Measurement

Differential cross sections for EBS

\[ \text{nat} \text{Mg} (d, d_0) \text{ natMg} \]

\[ E_{d, \text{lab}} = 2700 - 4250 \text{ keV} \]

Angles = 120° to 170°

Motor driven goniometer
Great angular accuracy (0.01 deg.)
Up to 4 targets
Water cooling available

Target: C + Mg + Au

A. Lagoyannis
I.N.P.P. Annual Meeting
Thursday 14/11/19
\[
\left( \frac{d\sigma}{d\Omega} \right)_{E,\theta,^{nat}N}^{Ruth} = \left( \frac{d\sigma}{d\Omega} \right)_{E',\theta,Au}^{Ruth} \\
\left( \frac{d\sigma}{d\Omega} \right)_{E,\theta,^{nat}N} = \frac{Y_{^{nat}N}}{Q \cdot \Omega \cdot N_t^{^{nat}N}} \\
\left( \frac{d\sigma}{d\Omega} \right)_{E',\theta,Au}^{Ruth} = \frac{Y_{Au}}{Q \cdot \Omega \cdot N_t^{Au}}
\]

Y : experimental yield (integrated counts of each peak)

Q : number of impinging deuteron ions in each case

\( \Omega \) : solid angle of the detector set at angle \( \theta \)

\( N_t^{N} \) : atomic areal density of N within the Si\(_3\)N\(_4\) layer

\( N_t^{Au} \) : atomic areal density of Au layer

\( \left( \frac{d\sigma}{d\Omega} \right)_{E',\theta,Au}^{Ruth} \) : differential cross section value of \(^{197}\text{Au}(d,d_0)^{197}\text{Au} \) elastic scattering at energy \( E' \) and angle \( \theta \)
Total statistical uncertainty < 5% in all cases
Differential CS Measurement - PIGE

- Electronically controlled turntable
- Initial angles: 0° – 55° – 90° – 165°
- 4 HPGe detectors (2 – 18%, 1 – 10%, 1 – 50%)
  placed between 25 and 30 cm from target
- Air cooled target
$^7\text{Li}(p,p'\gamma)^7\text{Li}$

$E_p = 2600 - 4050$ keV

Angles = $0^\circ - 55^\circ - 90^\circ - 165^\circ$

Differential CS Measurement - PIGE

A. Lagoyannis
I.N.P.P. Annual Meeting
Thursday 14/11/19
JET Measurements

ILW-1 Inner Wall Guard Limiter (IWGL) Wing

Experimental Setup
- Measurements at Ruder Boskovic Institute
- 3 MeV $^3$He micro-beam (for Deuteron)

Experimental Setup
- Measurements at Demokritos
- 1.35 MeV $^2$H milli-beam (for Carbon)

A. Lagoyannis
I.N.P.P. Annual Meeting
Thursday 14/11/19
Ion beam analysis using $^2\text{H}$ microbeam of 1.35 MeV and spot size 50×50 µm$^2$.

In some surfaces & castellation sides carbon agglomerates of about 50-200 µm diameter are observed.
JET Measurements

ILW-1 DP

ILW-1 IWGL CENTER

ILW-1 IWGL CENTER

A. Lagoyannis
I.N.P.P. Annual Meeting
Thursday 14/11/19
Future

CALIBRA is here
  Upgrade of the TANDEM vacuum system
  Installation of digital electronics for GASPAR (and other setups)
  Completion of the R-15 line to the Neoptolemos detector
  Design of the new goniometric table

Cross section measurements
  Characterization of the Neoptolemos detector with reactions
  Test of GASPAR with reactions
  Light elements deuteron induced reactions
  Proton induced gamma – ray reactions

Applications
  Upgrade of micro – beam setup for PIXE
  Continue with JET measurements
  Measurement of targets for University of York

Continue collaboration within the G4G ESA project