MOTIVATION: IS577 experiment @

Nucleus: $^{31}$Ar: Drip-line nucleus
- Half-life: 15.1(3) ms
- $T_z, J^*$: $-5/2^-, 5/2^+$
- $Q_{EC}$: 18.38(10) MeV

Decay modes: $\beta y, \beta p, \beta p y, \beta 2p, \beta 2py, \beta 3p$ and perhaps also $\beta 3py$

- Study of $\beta 2p$ and $\beta 3p$ channels (proton emission from levels near the threshold in $^{30}$S)
- IAS decay from $^{31}$Cl

SET-UP: MAGISOL Si plug-in chamber @

- Array of **Double Sided Si Strip Detectors** (DSSSD) and **PADs** in ΔE-E/telescope configuration located inside the new **MAGISOL Si-Plugin Chamber**
- Different thickness of DSSSDs for different proton energies

- **high efficiency** for multi-particle emission detection → **Solid angle**: 5x 9% of 4π
- **low cut-off energy** (150 keV).
- **Energy and Angular resolution**: 25 KeV, 3º

http://isolde-ids.web.cern.ch/isolde-ids/

- Courtesy of A. Perea

Irene Marroquín Alonso-ISOLDE WORKSHOP 2017 - CERN, Geneva
RESULTS: $^{33}\text{Ar}$ p-spectra...beyond calibration....

- Low energy thresholds for protons
- Very good energy resolution in all energy range

**NEW low energy proton peaks**

*762 keV peak is known


<table>
<thead>
<tr>
<th>DETECTOR</th>
<th>THICKNESS (um)</th>
<th>SOLID ANGLE (%)</th>
<th>ENERGY THRESHOLDS for protons (keV)</th>
<th>ANALYSIS CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>U1</td>
<td>300</td>
<td>7.4</td>
<td>350</td>
<td>$</td>
</tr>
<tr>
<td>U2</td>
<td>524</td>
<td>11.72</td>
<td>350</td>
<td>$\cdot E_f,E_b&gt;80\text{keV}$</td>
</tr>
<tr>
<td>U4</td>
<td>67</td>
<td>10.43</td>
<td>200</td>
<td>$\cdot \text{mul &gt; 6 excluded}$</td>
</tr>
<tr>
<td>U5</td>
<td>1000</td>
<td>9.6</td>
<td>-</td>
<td>$\cdot \text{TPROTON: 519 ms}$</td>
</tr>
<tr>
<td>U6</td>
<td>65</td>
<td>8.28</td>
<td>200</td>
<td></td>
</tr>
</tbody>
</table>
RESULTS: $^{33}$Ar p-spectra...beyond calibration....

**THIN TELESCOPES**

NEW low energy proton peaks

**THICK TELESCOPES**

NEW intermediate energy proton peaks

Irene Marroquín Alonso-ISOLDE WORKSHOP 2017 - CERN, Geneva

RESULTS: $^{33}\text{Ar}$ half-life

$^{33}\text{Ar}$ half-life value in good agreement with the literature value.

$y = A \cdot e^{-\lambda t} + C \rightarrow \tau = \frac{\ln 2}{\lambda}$

<table>
<thead>
<tr>
<th>Beam gate</th>
<th>U1: 295 um</th>
<th>U2: 524 um</th>
<th>U5: 1000 um</th>
<th>Weighted Average</th>
<th>Reference value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>400 ms</td>
<td>173.4±1.8</td>
<td>171.8±1.4</td>
<td>175.9±1.4</td>
<td>174.0±0.8</td>
<td>173.9±0.9</td>
</tr>
</tbody>
</table>

$^{31}\text{Ar}-Q_{1p}$ value

Do we see states in $^{31}\text{Cl}$ at high energy??

Present work has higher statistics and higher resolution than previous ones.


$$Q_{1p} = \frac{m_{30s}}{m_{30s} + m_p} (E_{31\text{Cl}} - S_p)$$
RESULTS: $^{31}$Ar: $Q_{2p}$ value

Do we see low energy protons from states of $^{30}$S near the threshold??

Excited levels in $^{30}$S near the particle threshold determine the $^{29}$P(pig)$^+$ reaction rate which influences the solar Si abundances.

$Q_{2p} = E_1 + E_2 + \frac{m_p}{m_{29p}}(E_1 + E_2 + 2\sqrt{E_1E_2\cos\theta_{2p}})$

$^{29}$P$^+(pig)$

$^{30}$S$^+(p)$

$^{31}$Cl

Gate: $Q_{2p}=7.6$ MeV

Irene Marroquín Alonso-ISOLDE WORKSHOP 2017 - CERN, Geneva
RESULTS: $^{31}$Ar: $Q_{2p}$ value

Do we see low energy protons from states of $^{30}$S near the threshold?!

$Q_{2p} = E_1 + E_2 + \frac{m_p}{m_{29p}}(E_1 + E_2 + 2\sqrt{E_1E_2cos\theta_{2p}})$

6.98 MeV-300 keV proton pair from 4.81 MeV-level is seen when angle between p-p pairs is calculated
RESULTS: $^{31}$Ar p-p coincidences

Do we see low energy protons from states of $^{30}$S near the threshold??

In p-p coincidence we also see the 300 keV proton from 4.81 MeV-level

6.98 MeV-p-gated p-spectrum

- Only energy gate on 6.98 MeV
- Energy gate
- Anticoincidence with PADs
- Edge strips excluded

OUI!!
RESULTS: \(^{31}\)Ar: Q\(_{3p}\) spectrum

When lowering the particle thresholds in the detectors, spectrum above is obtained.
-Work in progress-
Expected to be able to clean the spectrum by applying the time condition

<table>
<thead>
<tr>
<th>DETECTOR</th>
<th>THICKNESS (um)</th>
<th>SOLID ANGLE (%)</th>
<th>ENERGY THRESHOLDS (keV) (1)</th>
<th>ENERGY THRESHOLDS (keV) (2)</th>
<th>ANALYSIS CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>U1</td>
<td>300</td>
<td>7.4</td>
<td>350</td>
<td>1000</td>
<td>(</td>
</tr>
<tr>
<td>U2</td>
<td>524</td>
<td>11.72</td>
<td>400</td>
<td>1000</td>
<td>( E_f - E_b &gt; 80 \text{keV} )</td>
</tr>
<tr>
<td>U4</td>
<td>67</td>
<td>10.43</td>
<td>200</td>
<td>400</td>
<td>\text{Energy per telescope}</td>
</tr>
<tr>
<td>U5</td>
<td>1000</td>
<td>9.6</td>
<td>800</td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>U6</td>
<td>65</td>
<td>8.28</td>
<td>200</td>
<td>400</td>
<td></td>
</tr>
</tbody>
</table>
CONCLUSIONS - $^{31}\text{Ar}, \; ^{33}\text{Ar}$

**SUMMARY**

- $^{33}\text{Ar}$ used for calibration due to the **high resolution and low energy thresholds** of the detectors.

- **New proton transitions have been identified**, its placement in the level scheme is ongoing.

- Half-life of $^{33}\text{Ar}$ is determined **in agreement** with previous results.

- Study of $\beta 2p$ and $\beta 3p$ channels of $^{31}\text{Ar}$:
  - Proton emission from level near the proton threshold in $^{30}\text{S}$ is identified (4.81 MeV-level), relevant for nuclear astrophysics.
  - $^{31}\text{Ar}$-Q3p high energy contributions to the 3p branch identified, contributions from low energy protons is on progress.

**FUTURE WORK**

- Calculate $\frac{\Gamma_p}{\Gamma_\gamma}$ in particular for levels near the threshold in $^{30}\text{S}$: 4.69, 4.81 and 5.22 MeV levels.
- Spin assignment to the states in $^{30}\text{S}$. 
THANKS FOR YOUR ATTENTION

• O. Tengblad, E. Nácher, A. Perea, A. Garzón, I. Marroquín
  IEM-CSIC, Madrid, Spain
• L.M. Fraile, M.V. Vedia
  GFN-UCM, Madrid, Spain

  Department of Physics and Astronomy, Aarhus University, Denmark

• H. Johansson, B. Jonson, T. Nilsson
  Fundamental Physics, Chalmers University of Technology, Gothenburg, Sweden

• M.J.G. Borge, E. Rappisarda, M. Madurga, R. Lica
  ISOLDE, CERN, Geneva, Switzerland

• C. Sotty
  KU Leuven, Lovaina, Belgium

• C. Mazzocchi, A. A. Ciemny
  Institute of Experimental Physics, University of Physics, Warsaw

• C. Mihai, A. Negret, M. Stanoiu, S.A. Nae, A. E. Turturica
  IFIN-HH Bucharest - Magurele, ROMANIA
RESULTS: $^{33}$Ar p-spectra...beyond calibration.

<table>
<thead>
<tr>
<th>DETECTOR</th>
<th>THICKNESS (um)</th>
<th>SOLID ANGLE (%)</th>
<th>ENERGY THRESHOLDS for protons (keV)</th>
<th>ANALYSIS CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>U1</td>
<td>300</td>
<td>7.4</td>
<td>350</td>
<td>$</td>
</tr>
<tr>
<td>U2</td>
<td>524</td>
<td>11.72</td>
<td>350</td>
<td>$\text{mul} &gt; 6$ excluded·</td>
</tr>
<tr>
<td>U4</td>
<td>67</td>
<td>10.43</td>
<td>200</td>
<td>$E_f, E_b &gt; 80\text{keV}$·</td>
</tr>
<tr>
<td>U5</td>
<td>1000</td>
<td>9.6</td>
<td>-</td>
<td>$\text{TPROTON: 519 ms}$·</td>
</tr>
<tr>
<td>U6</td>
<td>65</td>
<td>8.28</td>
<td>200</td>
<td></td>
</tr>
</tbody>
</table>

Present work reproduces the previous intensities of proton peaks


Low energy thresholds for protons. IMPORTANT FOR LOW PROTON ENERGIES.
RESULTS: $^{33}$Ar p-spectra...beyond calibration....

THIN TELESCOPES

67 µm

NEW low energy proton peaks

Level identification: p-$\gamma$ coincidences

$^{33}$Ar $\gamma$-spectrum

$\varepsilon_{\gamma}(2\text{ MeV})=0.325\%$

$\varepsilon_{\gamma}(3\text{ MeV})=0.225\%$

$\varepsilon_{\gamma}(1332\text{ keV})=2.9\%$ (N. Adimi et al.)

$\varepsilon_{\gamma}(1332\text{ keV})=1.16\%$ (Gunvor et al.)

$\varepsilon_{\gamma}(1332\text{ keV})=0.40\%$ (Present work)
RESULTS: proton peak identification

Irene Marroquín Alonso- ISOLDE WORKSHOP 2017 - CERN, Geneva
RESULTS: proton peak identification

Intense peaks at high energies come from IAS: IAS decay to all levels in $^{30}$S


Good resolution at high energies: better demonstration than in previous measurements (IS476, IS339)
IS577 experiment @ ISOLDE Decay Station

- New permanent station devoted to $\beta$-decay measurements:
  - 4 HPGe clover-detectors surrounding the experimental chamber for high gamma ray detection efficiency
  - Modular experimental chamber (fast timing, neutron time-of-flight, beta and charge particle emission...)

MAGISOL Si plug-in chamber

$^{31}$Ar $1^+ @ 50$ keV
Yield: 1-2 $^{31}$Ar/μC

$^{31}$Ar

$4x$ HPGe clover-detectors

1 Clover $\rightarrow$ 4 crystals $\rightarrow$ 16 crystals in total

http://isolde-ids.web.cern.ch/isolde-ids/