Laboratory
Underground
Nuclear
Astrophysics

The LUNA II 400 kV Accelerator

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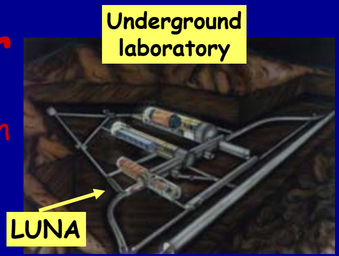
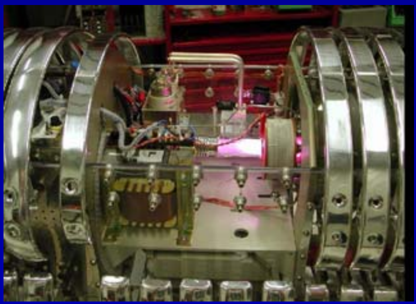




400 kV electrostatic accelerator (High Voltage Engineering Europe):

- High Voltage is generated by Inline Cockcroft-Walton power supply
- Radio Frequency oscillator excites the gas source (H_2,He)
- The plasma is positioned and confined by an axial magnetic field
- The ions are extracted by an electrode, which is part of the accelerator tube
- Everything imbedded in a tank with a gas mixture of N_2/CO_2 at 20 bar

An adjustable shortening rod permits a dynamical range from 50 to 400 kV, with a maximum current of 500 μA.

Calibration of the beam energy of the accelerator

Non resonant capture reaction with the low Q-value:

$^{12}C(p,\gamma)^{13}N$ Q = 1943.5keV

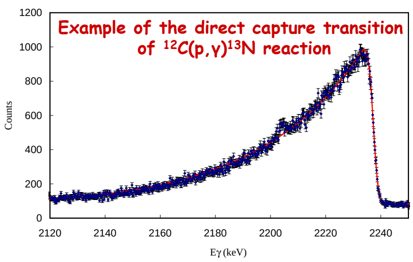
$$E_\gamma = Q + \frac{M_t}{m_p + M_t} E_p - \Delta E_{rec} + \Delta E_{Doppler}$$

- An accurate calibration of γ-spectra with radioactive sources (the Q-value of the reaction is in the range of γ emitted by sources)
- The proton energy is determined from the γ-ray energy measured (as the above relation shows)

^{12}C thick target.

High resolution Germanium detector placed at 0° with respect to the beam axis.

Energy range covered
130 keV ≤ E_p ≤ 400 keV

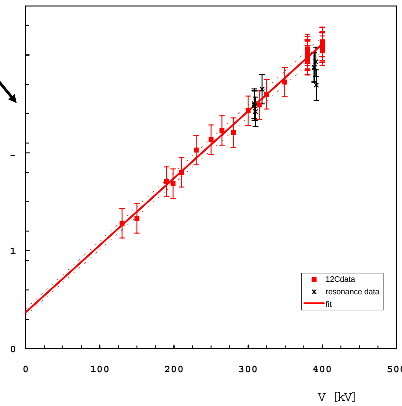


Example of the direct capture transition of $^{12}C(p,\gamma)^{13}N$ reaction

The γ-shape, in red, is due to the convolution of the cross section contribution with the detector resolution.

The half high energy edge of the peak corresponds to the incident proton energy.

The deviation of expected and observed proton energy (Δ) versus the nominal accelerator voltage (V=HV+PV).



The calibration has a statistical uncertainty of 0.06 keV.
The systematic error is 0.3 keV, due to the uncertainty of the reaction Q-value.

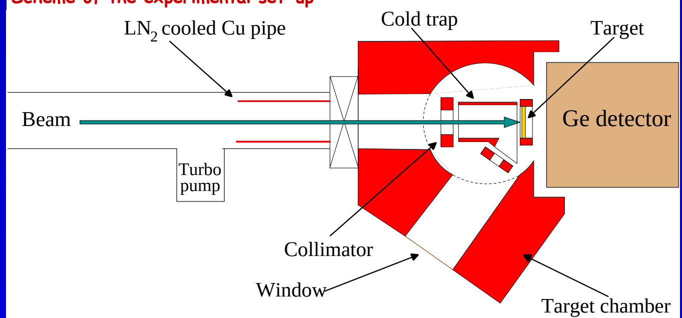
We consider a total accuracy of 0.3 keV.

Characterization of the energy spread of the ion beam and the stability

Narrow resonant capture reaction:

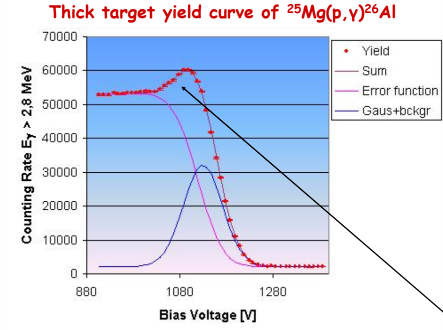
$^{25}Mg(p,\gamma)^{26}Al$ E_R = 389.24 keV Γ < 4 eV

Scheme of the experimental set-up



The experimental strategy consists in setting the beam energy at 1 keV above the resonance energy and varying it in steps of 10 eV with a positive voltage applied to the thick target of ^{25}Mg.

Thick target yield curve of $^{25}Mg(p,\gamma)^{26}Al$



The experimental beam energy spread ΔE_B is deduced by the position of the Gaussian and the error function corrected for the Doppler broadening

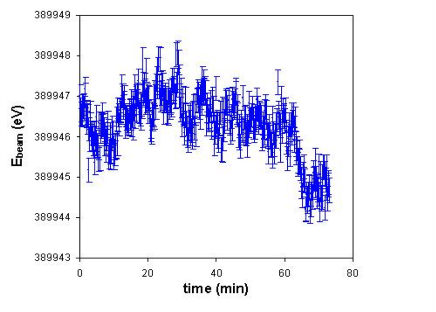
We obtained an energy spread of:

ΔE_B < 100 eV

The very low energy spread of the proton beam let us see the Lewis effect.

The long term stability of the accelerator is monitored with the yield variation observed setting the proton beam energy exactly at the resonance value.

Long term energy stability of 400 kV accelerator



Over a period of 73 minutes we observed a shift of ± 2 eV.