MONOENERGETIC NEUTRON BEAM FACILITY AT TSL

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Abstract

The cyclotron at the The Svedberg Laboratory, Uppsala has been equipped with a facility designed to produce high intensity, well-collimated and energetically well-defined neutron beams in the energy region 20 - 180 MeV. Several irradiation positions are available along the 25 m long neutron beam line.

1 INTRODUCTION

Proton beams from the cyclotron are used to produce neutrons by the $^{7}Li(p,n)^{7}Be$ reaction. The experimental area starts 8 m from the production target to provide for neutron beam collimation and time-of-flight gating which give a geometrically well defined and monoenergetic neutron beam.

The proton beam is bent away 45° from the original direction, dumped and monitored in a well shielded Faraday cup at the end of an 8 m long beam dump tunnel.

The most prominent features of the neutron production facility are the good shielding between the beam dump and the experimental area resulting in low background around the detectors. Another advantage is that neutron beam production can be performed in beam sharing mode with other ongoing experiments using high intensity proton beams. Using a switch magnet system, the proton beam can be directed to various beam lines following a preselected time schedule thus, increasing the beam time available for neutron production.

2 NEUTRON SOURCE AND BEAM LINES

A general overview of the neutron facility is shown in Fig.1. The switching magnet at the beginning of the Marble Hall directs the proton beam onto 100-850 mg/cm^2 thick discs (4-15 mm) of lithium, enriched to 99.98% in ^{7}Li. The discs are mounted in a water-cooled stainless-steel rig with four target holders, each with a diameter of 26 mm. The rig is remotely controlled from the control room for the positioning of the target to be used. One of the target holders contains a screen, viewed by a TV-camera for beam alignment and focussing (Fig.2)

The neutron beam produced in the forward direction is geometrically defined by a system of three collimators.

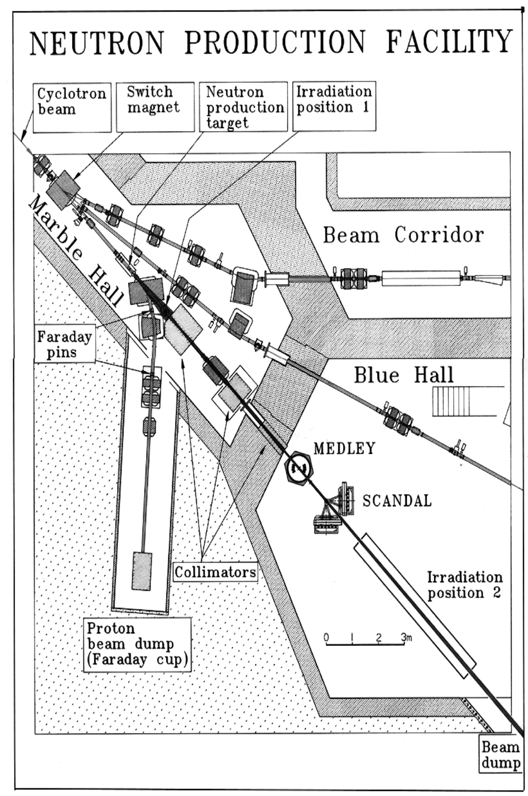

Figure 1: *Overview of the Uppsala (n,p) facility*

The first one consists of a 1 m long iron cylinder of revolver type with four axial holes with different openings. The cylinder is remotely controlled to collimate the neutron beam to the solid angles 60, 80 and 100 μsr, respectively. The channels have doubly conical shapes with a central waist defining the solid angle.

The second collimator is made of sandwiched iron and paraffin slabs, while the third one contains only iron slabs. This is also conical in shape with an entrance and exit opening of 60 mm and 75 mm, respectively, and serves as a scraper for the beam halo produced in the first collimator. Charged particles produced along the collimator channel are deflected by a clearing magnet.

A neutron irradiation facility with 60 times higher intensity is available 1.7 m downstream the production target. It makes use of neutrons produced at an angle between 0.8°and 1.6° off the initial beam axis and allows for long-term activation of targets with maximum dimensions of 25 x 60 mm^2 and does not interfere with other ongoing experiments further downstream.

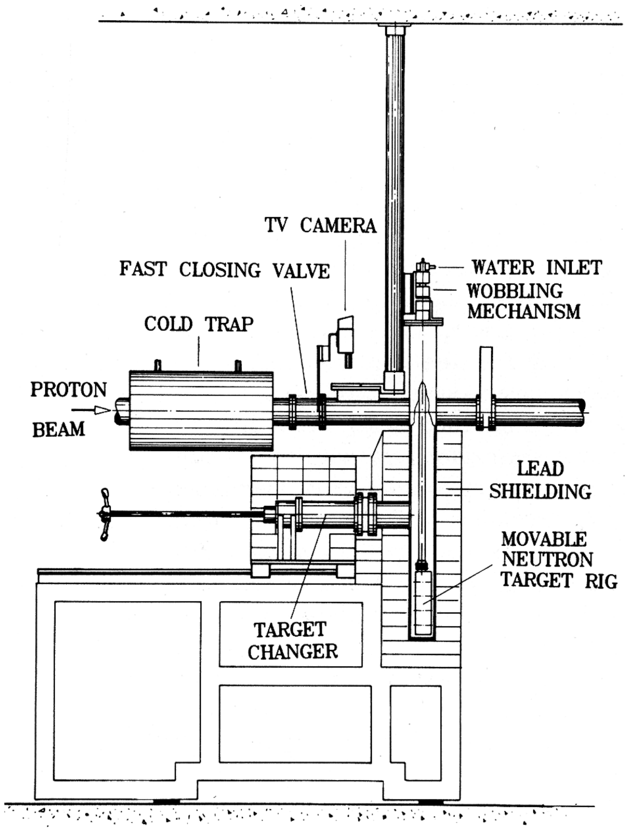

Figure 2: *Neutron-source arrangement*

As indicated in fig. 1, the proton beam is directed through the lithium target and further into a set of bending magnets and focused on a lead-shielded, water-cooled graphite block used as a Faraday cup at the end of the 8 m long beam dump tunnel. The integrated current from the Faraday-cup is used as a proton beam monitor but also as relative monitor for the neutron beam intensity.

An efficient dumping of the high intensity proton beam is important for various reasons. A high beam transmission through the magnet elements reduces the irradiation around the beam tubes and stabilizes the calculation of the neutron intensity.

A low-cost system has been installed to handle automatically the high-intensity beams in the beam dump line. The system is based on placing electrically insulated 1 mm stainless steel pins vertically along the diameter of the beam pipe in the path of the beam at two positions in the bending section. A beam profile is measured by scanning the beam with an upstream steering magnet. A routine has been written to automatically center the beam on the two pins. An example of a measured profile is shown in fig. 3 for 180 MeV protons with and without production target. The profiles were obtained by scanning the preceding bending magnet from 135 to 150 A.

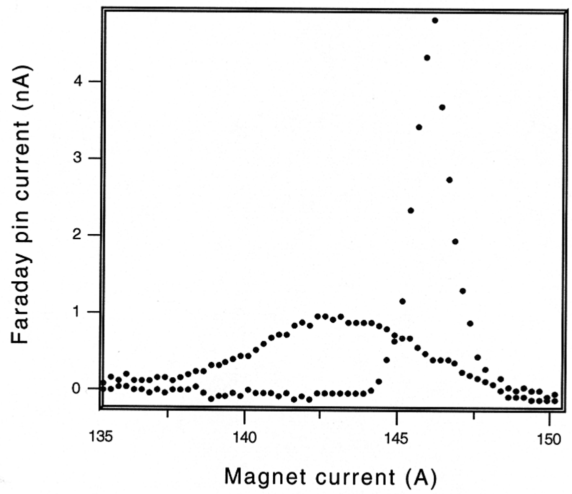

Figure 3: *Example of measured beam profile*

3 NEUTRON BEAM QUALITY

The ^{7}Li(p,n) reaction produces a neutron spectrum consisting of a full-energy peak, and, in addition, a low-energy continuum with the total intensity roughly equally distributed in each region. The peak corresponds to the unresolved ground state and first excited state at $E_x = 0.43$ MeV in ^{7}Be. The continuum is a consequence of ^{7}Be being left in higher excited states but also of multiple-particle emission.

The performance of the facility has been tested by measuring proton energy spectra from (n,p)-scattering on carbon- and polythen-targets at small angles for a neutron energy of about 100 MeV. The main part of the continuum can be eliminated by TOF-gating as can be seen from the lower curve in Fig. 3.

The energy spectrum of the neutron beam obtained in this way covers an energy range of 30 - 40 MeV down from the high-energy peak. For some applications it is of importance to know even the low energy part of the neutron beam. These properties have been determined at a position close to the production target in the Marble Hall and also in the Blue Hall in the collimated neutron beam[1]. Thin film breakdown counters were used in the detection of fission fragments from neutron reactions in ^{235}U and ^{232}Th combined with TOF techniques. The low energy continuum was rather flat with a near-thermal part which was 1% of the high energy neutron flux when measured close to the production target. The corresponding ratio was several orders of magnitude lower when measured in the collimated neutron beam far from the production target.

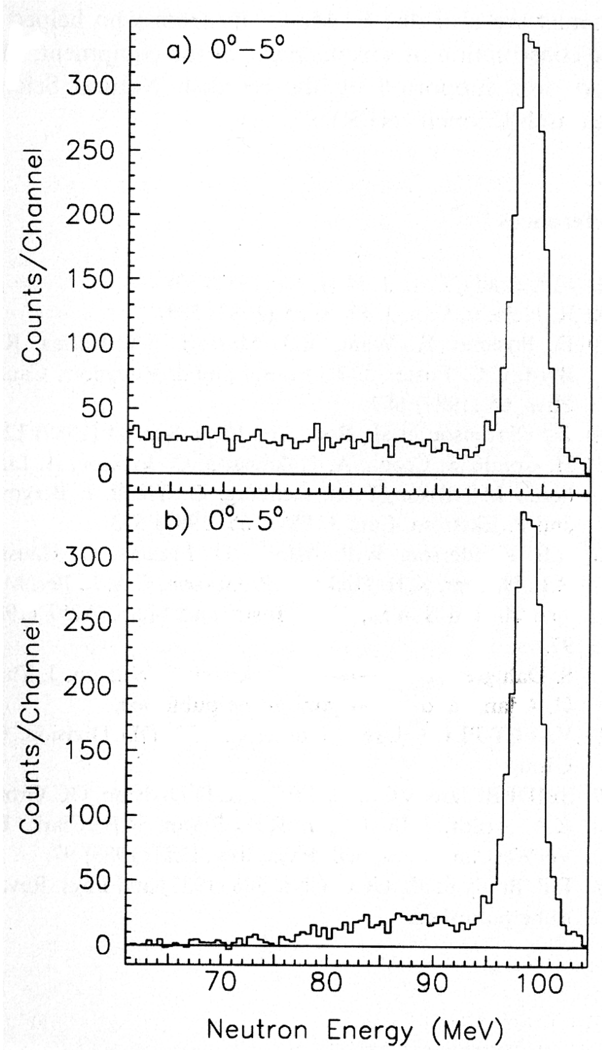

Figure 4: *(a) Reconstructed energy spectrum of incoming neutrons, using a proton spectrum in the angular range 0–5°, obtained with a CH_2 target, and subtracting the contribution from the $^{12}C(n,p)^{12}B$ reaction. (b) The same spectrum as in (a) using TOF-gating.*

The collimated neutron beam has the intensity: $5 \cdot 10^4$ neutrons/mm ^{7}Li target/µA of incident proton beam over a beam spot with a solid angle of 60 µsr. The neutron flux density is 60 times higher at the irradiation position situated close to the production target.

The proton beam intensity on target is calculated from the on-line measurement of the dumped proton beam in the Faraday cup, corrected for the dumping efficiency. Beam intensities of 0.2 to 10 µA are available with the smaller intensities at the higher proton energies.

It is intended in the near future to install an in-beam neutron monitor designed and manufactured by a group from Russia[1]. The monitor consists of a thin ^{238}U-foil connected to a Si-detector. Neutron-produced fission fragments cause break-downs in the Si-detector with a count rate proportional to the neutron flux.

4 EXPERIMENTAL PROGRAM

The neutron beam facility at the The Svedberg Laboratory is available for users with experimental programs ranging from basic science to industry research. Presently (1998) we have users within the following areas:

Basic nuclear research

- Neutron - proton scattering
- Elastic neutron scattering on nuclei
- Charge exchange (n,p) reactions in nuclei
- Fast-neutron fission dynamics

Energy applications

- Transmutation research

Medical applications

- Fast-neutron cancer therapy
- Calibrations of neutron dosimeters

Technical applications

- Single-event upsets
- Detector tests

Astrophysics

- Spallation-like reactions

Besides a large number of universities and research institutes from many countries the facility is also used by Ericsson, SAAB and radiation protection authorities from several european countries.

REFERENCES

[1] A. Prokofyev et al PM for TSL, Uppsala, May 1997.