Profile LFR-36

nELBE

GERMANY

GENERAL INFORMATION

NAME OF THE FACILITY	PhotoNeutronsource at the ELBE accelerator
ACRONYM	nELBE
COOLANT(S) OF THE FACILITY	Liquid lead
LOCATION (address):	Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Bautzner Landstrasse 400, D-01328 Dresden, Germany
OPERATOR	HZDR
CONTACT PERSON (name, address, institute, function, telephone, email):	Arnd Junghans, HZDR, Bautzner Landstr. 400, 01328 Dresden, Germany, group leader Nuclear Data, Tel. +49 351 2603589, a.junghans@hzdr.de
STATUS OF THE FACILITY	In operation
Start of operation (date):	2013

MAIN RESEARCH FIELD(S)

- ☐ Zero power facility for V&V and licensing purposes
- ☐ Design Basis Accidents (DBA) and Design Extended Conditions (DEC)
- ☐ Thermal-hydraulics
- ☐ Coolant chemistry
- ☒ Materials
- ☐ Systems and components
- ☐ Instrumentation & ISI&R

TECHNICAL DESCRIPTION

Description of the facility

The nELBE neutron time of flight facility uses a liquid-lead circuit as a very compact neutron producing target [1] [2]. The neutrons are produced in photonuclear reactions from bremsstrahlung created by the intense electron beam pulses from the superconducting electron accelerator ELBE. nELBE is the world's only photoneutron source at a superconducting electron accelerator. Transnational access to nELBE is available with EURATOM project support [3] and as part of the Helmholtz user facility "Center for High-Power Radiation Sources" at HZDR. The short beam pulses (about 5 ps FWHM) delivered by the superconducting electron accelerator provide the basis for an excellent time resolution for neutron time-of-flight experiments while the pulse repetition rates can be varied between single pulses and 26 MHz according to the demands of the experiments. The typical rates are 102 and 203 kHz, resulting in a neutron pulse repetition period of about 5 – 10 µs. With the existing thermionic electron source typical bunch charges of 80 pC are realized allowing a moderate average beam current of 16 µA at a repetition rate of 203 kHz. The corresponding neutron source strength has been measured to be 10^{11} neutrons/s. The characteristic parameters of the neutron spectrum are given in Table 1. The neutron spectral rate determined with the H19 Fission chamber from PTB, Braunschweig is shown in Figure 1.

Table 1 Characteristic parameters of the nELBE neutron beam

Repetition rate	102, 203, 406 kHz
Flight path	5 – 11 m
Source strength (30 MeV, 15µA)	1.6 10^{11} n/s
Intensity on target	2.5 10^4 n/cm²s
Energy range	50 keV – 10 MeV
Energy resolution @ 1 MeV	≈1 %

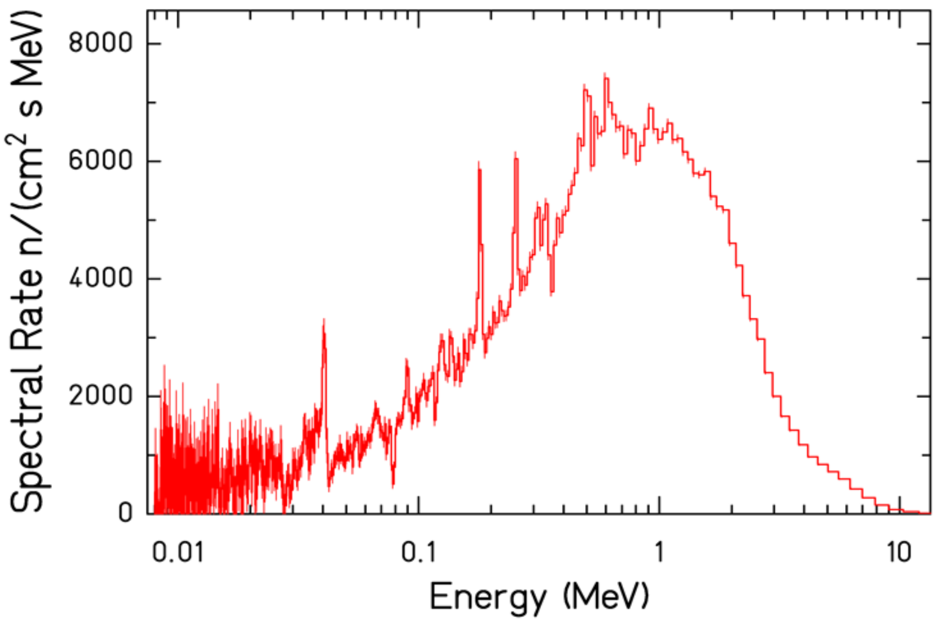

Figure 1 Fast neutron spectrum measured with the H19 ^{235}U fission chamber of PTB, Braunschweig. The measurement time was 49.4 h with an average electron beam currrent of I_{e-} = 15 µA and energy E_{e-} = 31 MeV with a flight path of 618 cm

The fast neutron spectrum is used to extend the range of accurate nuclear data for science and technology [1, 3]. Figure 2 shows the floorplan of the nELBE time of flight facility. The research programm concentrates on measurements of inelastic and elastic neutron scattering, total neutron cross sections and neutron-induced fission cross sections [1, 4, 5, 3]. Due to the cw operation of the electron beam, the bremsstrahlung pulses in the beam have a comparably low instantaneous flux allowing for favourable background conditions for the detection of neutrons that start to arrive at the experiment typically already 100 ns after the bremsstrahlung. The flight path can be kept short and thus the neutron intensity is increased. The neutron spectrum is not moderated and there is very little background from delayed gamma rays [6].

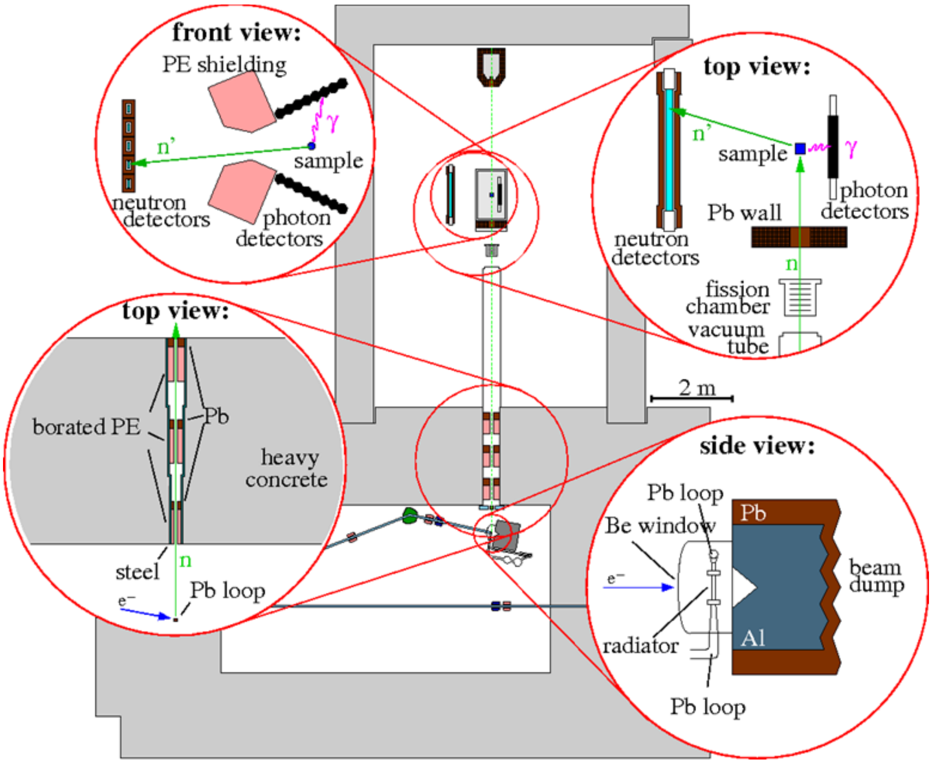

Figure 2 Floorplan of the nELBE time of flight facility. The Liquid lead circuit used as a compact photoneutron source is located at the end of the electron beam line (inset on the lower right shows a cross section view). The neutron beam is formed in a collimator consisting of borated polyethylene and Pb (inset on lower left). The upper part shows the time of flight hall with a detector setup for a double time of flight measurement.

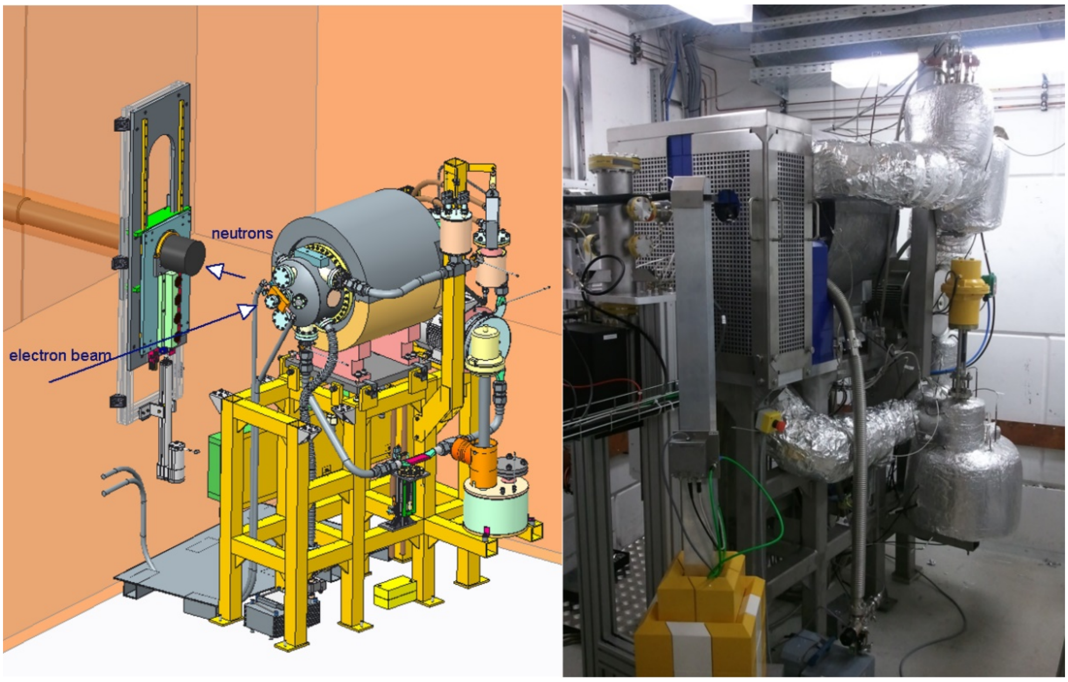

Figure 3 Left panel: 3D rendering of the nELBE liquid lead circuit showing the components.
Right Panel: Photograph of the liquid lead circuit with insulation and lead shielding

The electron beam passes through a beryllium window mounted on a stainless-steel vacuum chamber and hits the neutron producing target, consisting of a molybdenum channel confining the liquid lead. The channel has a rhombic cross section with 11 mm side length. The use of liquid lead allows to realize a very compact neutron producing volume of about 1 cm^3. The power density created by the electron beam is about 1 -10 kW /cm^3. The dissipated heat can be cooled by a heat exchanger using InGaSn as a heat transfer medium. Liquid lead is advantageous from a radiological standpoint as only little long-lived radioactivity is created by the electron beam in the lead. About ½ of the beam power is deposited in the liquid lead. The beam is stopped in a large water cooled aluminium beam dump attached to the vacuum vessel, see Figure 3

The liquid-lead and cooling technology was developed using the HZDR ELEFANT facility as a prototype. Figure 3 shows the design of the liquid lead circuit at nELBE [8]. The liqud lead is kept under argon protective atmosphere and flows through stainless steel tubes and hoses with a typical diameter of 28 mm. The circuit is heated by ohmic heaters of a total electric power of approx. 5 kW to the operating temperature of ca. 700 K. The liquid lead is pumped by an induction pump through the whole circuit including the vacuum vessel with molybdenum channel as neutron producing target, overflow vessel with filling level sensors, heat exchanger, and a rectangular cross section test channel, where the lead flow is measured using a magnetic flywheel flow meter [7]. The lead velocity is in the order of 1-5 m/s. The liquid lead (volume 10 l) can be filled and drained into a storage vessel.

The liquid lead loop is operated remotely and controlled online using a Simatic S7 measurement and control system including automated routines for heating up, filling, operation and draining, and cooling down. It has been operated very reliably over 6000 hours without failures. The control system also provides an interlock to the accelerator control to ensure save operating conditons of cooling and lead flow.

Acceptance of radioactive material

The photoneutron source is located in the radiation controlled area of the electron accelerator. It is one of the end stations of the electron beam. Enclosed radioactive samples can be handled within the limits of the relevant permissions.

COMPLETED EXPERIMENTAL CAMPAIGNS: MAIN RESULTS AND ACHIEVEMENTS

- Coupling of a liquid lead circuit and a superconducting electron accelerator to form a unique photoneutron source with a fast neutron spectrum
- Long-term operation as a neutron production target at the photoneutron source nELBE at HZDR (over 6000 hours) with average electron beam currents from 0.1 to 30 µA and electron energy of 30 MeV
- Experimental setups for measurement of fast neutron-induced reactions have been developed: neutron transmission for total cross sections, double time-of-flight setup for inelastic scattering, neutron-induced fission using parallel plate fisson chambers.

PLANNED EXPERIMENTS (including time schedule)

- Continued use (since 2013) as a facility for external users for nuclear data measurements with fast neutrons
- Measurements of neutron scattering and neutron induced fission within the EURATOM supported transnational access for energy and non-energy applications [8]

TRAINING ACTIVITIES

Training activities can be agreed with HZDR for the operation of the experimental campaign under the supervision of HZDR qualified staff. Education and Training activities will be supported by the EURATOM proposal ARIEL (Call NFRP-2018-7 SEP-210524952).

References (all publication in English)

[1] R. Beyer, E. Birgersson, Z. Elekes, A. Ferrari, E. Grosse, R. Hannaske, A. Junghans, T. Kögler, R. Massarczyk, A. Matic, R. Nolte, R. Schwengner and A. Wagner.*Nucl. Inst. Meth. A 723 (2013) 151.*

[2] K. Bartholomew, T. Beglya, T. Chiaveri, T. Desai, T. Katabuchi, X. Ledoux, R. Nolte, S. Oberstedt, D. Ridikas and S. Simakov, "Compendium of Neutron Beam Facilities for High Precision Nuclear Data Measurements," IAEA TECDOC 1743, 2014.

[3] A. Junghans, R. Beyer, Z. Elekes, E. Grosse, R. Hannaske, T. Kögler, R. Massarczyk, R. Schwengner and A. Wagner, *Nuclear Data Sheets,* vol. 119, pp. 349-252, 2014.

[4] R. Beyer, R. Schwengner, R. Hannaske, A. Junghans, R. Massarczyk, M. Anders, D. Bemmerer, A. Ferrari, A. Hartmann, T. Kögler, M. Röder, K. Schmidt and A. Wagner.*Nuclear Physics A 927 (2014) 41.*

[5] R. Hannaske, Z. Elekes, R. Beyer, A. Junghans, D. Bemmerer, E. Birgersson, A. Ferrari, E. Grosse, M. Kempe, T. Kögler, M. Marta, R. Massarczyk, A. Matic, G. Schramm, R. Schwengner and A. Wagner.*Eur. Phys. Jour. A49 (2013) 137.*

[6] P. Schillebeeckx, B. Becker, Y. Danon, K. Guber, H. Harada, J. Heyse, A. R. Junghans, S. Kopecky, C. Massimi, M. C. Moxon, N. Otuka, I. Sirakov and K. Volev.*Nuclear Data Sheets 113(2012), 3054-3100.*

[7] S. Eckert, D. Buchenau, G. Gerbeth, F. Stefani and F.-P. Weiss.*J. Nucl. Sci. Techn. 48, (2011) 490-498.*

[8] E. Gonzalez, "CHANDA," [Online]. Available: http://win.ciemat.es/chanda/.

[9] E. Altstadt, C. Beckert, H. Freiesleben, V. Galindo, E. Grosse, A. Junghans, J. Klug, B. Naumann, S. Schneider, R. Schlenk, A. Wagner and F.-P. Weiss.*Ann. Nucl. Ene. 34 (2007) 36.*