3.9 The CERN n_TOF Facility: Catching Neutrons on the Fly

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High precision neutron cross-section data are of importance for a wide variety of research fields in basic and applied nuclear physics: In nuclear astrophysics data on neutron–nucleus reactions are essential to understand the production of heavy elements in the Universe, which occurs mainly through neutron capture processes during the various phases of stellar evolution. In nuclear technology, renewed interest in nuclear energy production has triggered studies aimed at developing future generation systems that would address safety, proliferation and waste concerns. For these applications the available nuclear data for many nuclides are of insufficient accuracy or even not existing.

Based on these motivations and given that the PS can produce proton pulses of very high intensity, the neutron Time-Of-Flight facility n_TOF has been proposed and constructed at CERN [49, 50], Fig. 3.25. It is based on the insight that such an intense proton bunch extracted from the PS could produce an intense pulse of spallation neutrons, produced in a wide range of energies and a correspondingly large spread in velocities. Thus, the neutron arrival time at a detector, located far downstream from the target, gives the neutron velocity and hence, its kinetic energy. Measuring precisely the neutron-time-of-flight produces a beam of neutrons with excellent energy resolution.

Commissioning and operation started in 2001 with performances ultimately matching design after a substantial optimization of shielding. The PS provides up to 8×10^{12} protons per pulse every 1.2 seconds (or multiples thereof). These proton pulses of 20 GeV/c momentum impinge on a 1.3 ton cylindrical lead target 40 cm in length and 60 cm in diameter producing a bunch of 2×10^{15} neutrons of 6 ns width. The high neutron flux, the low repetition rates and the excellent relative energy resolution, reaching values as low as 3×10^{-4} for 1 eV to 10 KeV neutrons, open new possibilities for high precision cross section measurements from thermal to a few GeV energy on stable and, importantly, radioactive isotopes.

The n_TOF target [51] is cooled by a 1 cm water layer and with a subsequent layer of 4 cm of water or borated water (H_2O + 1.28%H_3BO_3, fraction in mass). Initially fast neutrons are moderated into the desired energy spectrum, which ranges down to thermal energies. The experimental area (EAR1) begins at 182 m from the spallation target and has a length of 7.9 m. Along the evacuated beam line a sweeping magnet (200 cm long, 44 cm gap and 3.6 Tm bending power) deflects and removes the charged particles in the beam. In a typical experiment, a sample is placed in the neutron beam, and the reaction products are detected with

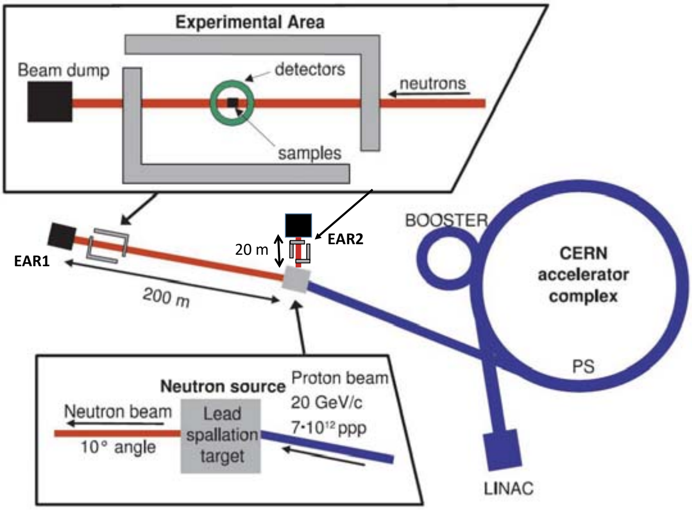

Fig. 3.25. Layout of the n_TOF facility [51].

specialized instruments. The reaction probability is measured as a function of the incident neutron flight time and hence its energy.

To extend the measurements on stable and short-lived isotopes, with very low cross sections or available only in extremely small quantities, the n_TOF Collaboration proposed the construction of a new experimental area (EAR2) at a shorter distance from the spallation target to exploit a much higher neutron flux [52]. It was convenient and advantageous to build the new experimental area on the surface, directly above the pit hosting the spallation target, which is located approximately 20 m below the surface. This layout reduces the time-of-flight between target and detectors by a factor 10 and increases the neutron flux by a factor of around 25 relative to EAR1. It allows measurements of correspondingly smaller samples, of smaller cross sections or in a shorter time. The factor 10 shorter flight time is also a crucial advantage for the study of radioactive substances. The spread in arrival time ΔT of neutrons in an energy interval ΔE and hence the necessary sensitive time of the detectors is reduced by the same factor 10. Reducing the measurement time reduces the dominant background from the decay of the radioactive isotope under study. The total gain in sensitivity of up to a factor of 250 relative to EAR1 means that isotopes with half-lives as short as a few months can now be studied [53].

The CERN n_TOF facility is worldwide unique due to its very wide energy spectrum and intensity of neutrons. It is home of a rich and in many ways unique scientific programme [52].

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