A MACRO-PULSED 1.2 MW PROTON BEAM FOR THE PSI ULTRA COLD NEUTRON SOURCE

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Abstract

At PSI, a new and very intensive Ultra-Cold Neutron (UCN) source based on the spallation principle will start operation at the end of 2009. From then on, two neutron spallation sources - the continuous wave SINQ and the macro-pulsed UCN source - will be running concurrently at PSI. The 590 MeV, 1.2 MW proton beam will be switched towards the new spallation target for about 8 s every 800 s. This operation can be accomplished by means of a fast kicker magnet with a rise-time shorter than 1 ms. A beam dump capable of absorbing the full-intensity beam for a few milliseconds has been installed after the last bending magnet so that the kicking process and the beam diagnostic can be checked well before the UCN facility will be ready for operation. Recent tests have demonstrated the capability of switching the 1.2 MW beam with negligible losses and to center it through the beam line by using fast beam position monitors. Much longer beam pulses (up to 6 seconds) with reduced beam intensity have also been performed successfully.

INTRODUCTION

A new UCN source based on the spallation principle is under construction at PSI [1]. Neutrons will be produced by switching the 590 MeV, 2 mA proton beam coming from the PSI ring cyclotron into a dedicated beam line. The switching procedure will be based on a regular scheme of 8 seconds beam pulse every 800 seconds (duty cycle of 1%). During the remaining 99% of the time, the beam will follow the usual path through the two meson production targets and to the SINQ neutron spallation target. During the UCN pulse, neutrons will be produced by a spallation lead target, then thermalized in D_2O and finally cooled down to UCN in solid deuterium at 5 K. The generated ultra cold neutrons will be stored into a tank and guided to experiments. The estimated UCN density is larger than 1000 UCN/cm^3 in a typical experiment, which corresponds to an increase of almost two orders of magnitude with respect to the best source currently available (ILL).

The PSI UCN source is expected to come into operation at the end of 2009. PSI will then concurrently run two spallation sources by means of the same accelerator facility.

OVERVIEW OF THE BEAM LINE

A schematic view of the UCN beam line is given in Fig. 2. The 2 mA proton beam extracted from the ring cyclotron is normally transferred to the targets M, E and SINQ via the proton channel. An electrostatic splitter (EHT) [2] can deviate a small portion of the beam (up to 20 μA) through a magnetic septum (ABS) providing the deflection towards the nearby UCN line used till 2005 for medical proton therapy or proton irradiation [3,4]. The full-intensity beam can be diverted to the UCN line thanks to a fast kicker magnet installed in front of the splitter for this purpose in 2002 and already tested at that time with 20 μA beam intensity [5]. Downstream of the last bending magnet (ABK2) the beam will be blown up by a quadrupole magnet and then collimated before reaching the UCN target, where the beam spot will have a 4σ diameter of about 160 mm.

Fast beam position monitors (BPMs, 50 kHz sampling rate) allow the beam trajectory to be checked and, if needed, corrected during a 5 ms pulse. At the same time, several beam loss monitors can trigger an interlock in less than 1 ms.

Behind ABK2 a beam dump has been placed which can absorb the 2 mA beam for 10 ms. This enables to test the kicking procedure and the beam diagnostics independently from UCN operation.

THE FAST KICKER

Heart of the beam switching system is the fast kicker. This magnet features a window frame design which minimizes its inductance. The rise- and fall-time are kept as short as possible by using a ferrite yoke. The vacuum chamber is made of insulating ceramic material in order to avoid eddy currents. The timing of the power supply has been tuned so that the first 85% of the beam angular deflection can be reached within 1 ms. This requirement was made necessary by the fact that, during its transition, the beam hits the tungsten collimator of the septum magnet. During the remaining part, the beam transition is made slower in order to avoid overshooting.

The kicking scheme includes two very short kicks (5 ms) to be performed before each 8 s long kick. During these short kicks, the beam trajectory is checked and correction to the steering system can be applied in order to make sure that the UCN line is ready to accept the incoming 2 mA beam for a longer time. This is a crucial operation, because at some locations the 1.2 MW beam can melt the steel vacuum chamber within 10 ms.

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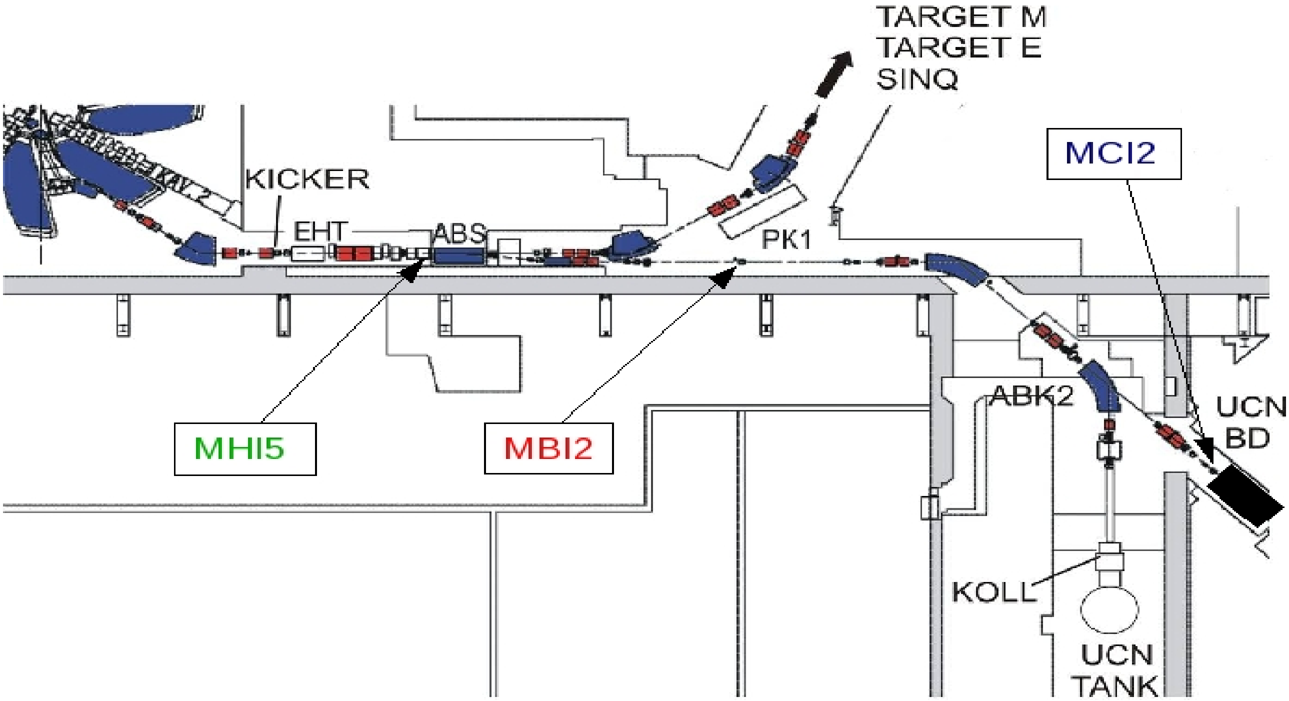

Figure 1: A schematic view of the UCN beam line. The different components are described in the text. MHI5, MBI2 and MCI2 are the three beam loss monitors whose measurements are shown in Fig. 3.

UCN TESTS IN 2008

Through the whole 2008 running period of the PSI proton facility, a remarkable test program of the UCN beam line has been carried out. During weekly beam development sessions the beam has been sent to the UCN beam dump, first by using the electrostatic splitter and then by kicking always larger amounts of beam, till the full-intensity beam could be kicked.

Beam Trajectory Control

A timing system and a software application have been developed which trigger a short pulse to UCN, check the beam trajectory by reading out the measurements of beam position monitors (Fig. 2), provide feedback to the steering magnets in case corrections are needed, and finally iterate this procedure till the beam is centered. At that point, a 8 s long pulse can be allowed. Furthermore, the system shifts the interlock thresholds of the beam loss monitors during the first 3 ms of each of the two transition phases when the beam losses are largest.

The tests have demonstrated that the BPMs and the timing system are fast enough to provide the trajectory corrections within a 5 ms pulse. Moreover, the application software showed very nice performance and did not need substantial modifications during the test phase.

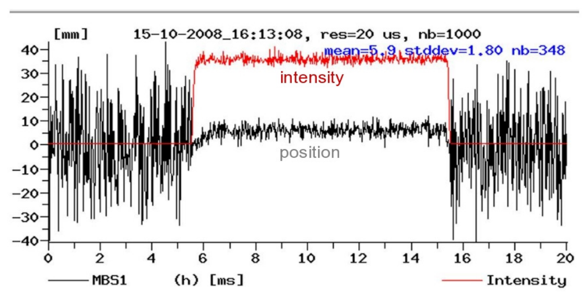

Figure 2: A beam position measurement during a UCN full-intensity short kick. The beam deflection by the kicker magnet can clearly be seen during the first 2 ms of the kick. The measurement of the beam intensity is superposed to the beam position. At zero beam intensity, the position measurement is meaningless.

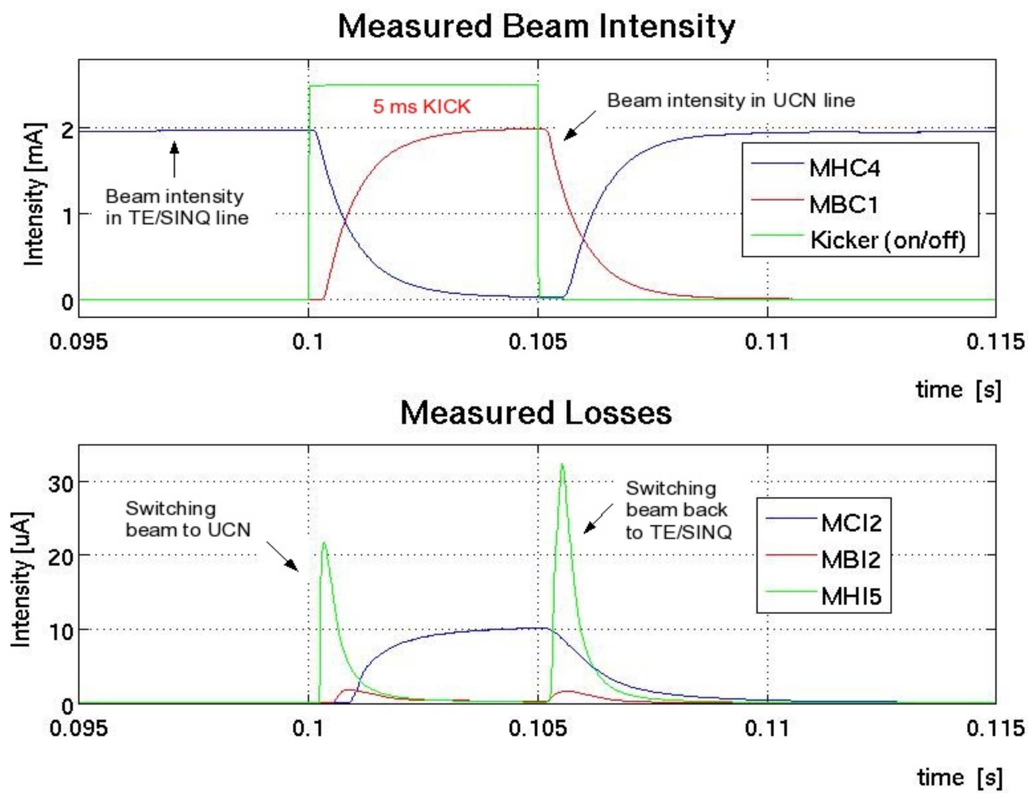

Figure 3: Measurements of beam intensity and losses during a 5 ms UCN kick at full intensity. The three loss monitors are only a subset of the several ionization chambers employed in the line. Their positions are shown in Fig. 1.

Measurements of Beam Losses

The UCN beam line protection system employs fast ionization chambers as beam loss monitors capable of a reaction time in the ms range. This system, mandatory due to the high beam power, would on the other hand trigger an interlock during the beam transition phase, when a large portion of beam is lost on the septum collimator for a fraction of a ms. This occurrence is prevented through the timing system by temporary increasing the loss monitors thresholds by three orders of magnitude (3 ms starting from the beginning of the transition).

Figure 3 shows the losses measured by three different monitors, along with the beam intensity during a 5 ms kick at full power. During the transitions, the losses are clearly concentrated upstream of the septum magnet (MHI5) as expected from the presence of the tungsten collimator. Nevertheless, due to the very fast kicking process and the low duty cycle, the accumulation of losses at the collimator over a long running period is negligible [5]. Downstream of the septum, beam losses are almost absent even during transitions (MBI2). Close to the beam dump (MCI2), losses are of course present during the entire pulse.

CONCLUSION

During the year 2008, successful tests of the PSI UCN beam line have been carried out by kicking the 1.2 MW proton beam for up to 10 ms to the UCN beam dump. The fast kicker magnet, the timing system and the beam diagnostic have shown reliable operation. During the winter 2009 shut-down, the installation of diagnostics elements in the last part of the beam line has been completed. The UCN moderator and storage tank has been placed in position along with the UCN lead target. The cryogenic system is currently under construction. First neutrons are expected by the end of 2009.

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