FAST KICKER EXTRACTION AT COSY-JUELICH

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Abstract

For the usual operation of the cooler synchrotron COSY two kinds of beam extraction were foreseen and realized: resonant extraction and stochastic extraction. Now a fast beam extraction for the new experiment JESSICA (Jülich Experimental Spallation Target Setup in COSY Area) is of great importance for prototyping the high power target of the European Spallation Source.
First experiments using the kicker, originally installed for diagnostic purposes in the COSY ring, are reported. Special emphasis is given for beam diagnostics developments in the extraction beamline for measuring intensive fast proton pulses. To measure beam current and time structure a wall current monitor was installed in the extraction beam line. For more sensitive measurements in a wide range a so called universal spill measurement device, consisting of scintillators and a ionisation chamber was developed.

1 INTRODUCTION

According to the demands of the physics experiments (e.g. long spill time) to kinds of beam extraction were foreseen and realized for usual operation of the cooler synchrotron COSY: resonant extraction and stochastic extraction. Now a fast beam extraction for the new experiment JESSICA (Jülich Experimental Spallation Target Setup in COSY Area) [1] is of great importance for prototyping the high power target of the European Spallation Source. A full-size liquid Hg target (Fig. 1) will be placed in the extraction beamline and irradiated with short pulsed proton beam of COSY to produce a low intensity pulsed neutron beam. A variety of ambient temperature and cold moderators will be investigated at various positions relative to the target which is surrounded by a lead reflector. The aim is to validate by experiments the complex simulation methods of particle production, interaction and transport to optimize the technical layout of an ESS-type target-moderator-reflector system. For the experiments proton pulses with energy < 1.5 GeV, pulse length < 1µs and intensity of more than 10^7 protons per pulse are needed.
The kicker magnet in the COSY ring, originally installed for beam diagnostic measurements [2], is used for first experiments of fast beam extraction. The procedure starts in the same manner as for resonant beam extraction for external experiments. A closed orbit bump is located in

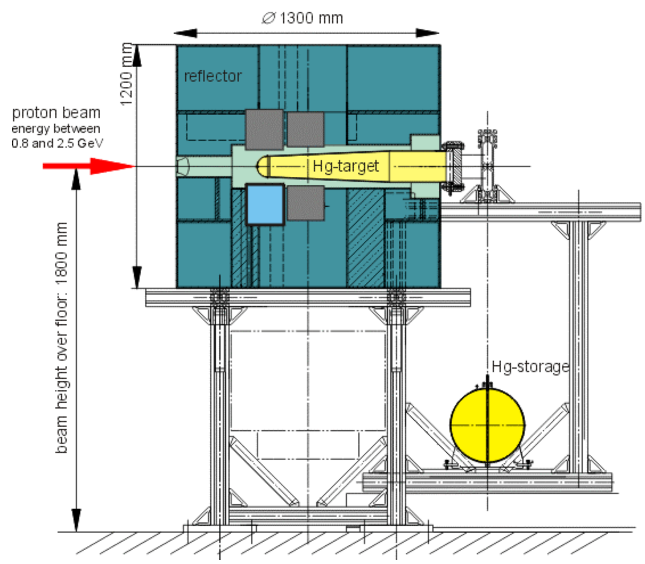

Figure 1: JESSICA Target-Moderator-Reflector Test Facility [1].

the horizontal plane near the electrostatic septum. By means of the kicker magnet the beam bunch (width about 200 - 500 ns) is short-time deflected (kicker pulse width 0.75 - 2 µs, rise- and falltime < 200ns). The kicker excitation is synchronized with respect to the COSY-rf signal and can be adjusted in time by programmable delay, so a unique deflection of the total bunch can be performed (bunch synchronous kick). The repetition rate of the kicker excitation is 1 Hz. The minimal COSY cycle time varies from 2 s in the case of low energy to 5 s in the case of the highest energy. For increasing the intensity of kicked and extracted beam a reduction of beam emittance is necessary. In our case electron cooling for some seconds at injection energy is used.

2 BEAM INSTRUMENTATION

2.1 Wall Current Monitor

For non-beam disturbing diagnostics of intensity and time structure of the kicked and extracted beam the wall current monitor (WCM) [3], which was formerly located in the ring, was installed in the experimental area of JESSICA. The WCM is a broadband pick-up for detailed measurements of beam pulse intensity and shape. The method of operation is the measurement of the image current in the wall of the vacuum tube, which corresponds (apart from the sign) to the beam pulse current. For this purpose a gap is inserted in the tube, which is sealed by ceramic insulator and bridged by eight symmetrically arranged resistors. The wall current is forced through these resistors and generates signals, which are picked – up by semi rigid transmission lines and added together by rf- combiners to the resulting WCM signal. This is proportional to the beam pulse current with transfer impedance of Z = 10 Ω in this case. The frequency transfer characteristic is flat in a band pass region of 100 kHz- 200 MHz. The upper frequency cutoff is determined by the gap capacitance and the lower one by the inductance around the gap which is realized by ferrite rings mounted over the vacuum tube near the gap.

2.2 Spill Detector

When high energy ion beams are extracted from synchrotrons it is necessary to measure the total number of extracted particles within one cycle to quantify the efficiency of the extraction. The total particle number is found by integrating the particle rate over the cycle time. Due to fluctuations within the cycle the rate must be measured absolutely and with proper time resolution of < 1ms. The major challenge comes from the fact that the extracted rates may vary with stochastic extraction over many orders of magnitude (at COSY from 10^4/s to 10^{10}/s).

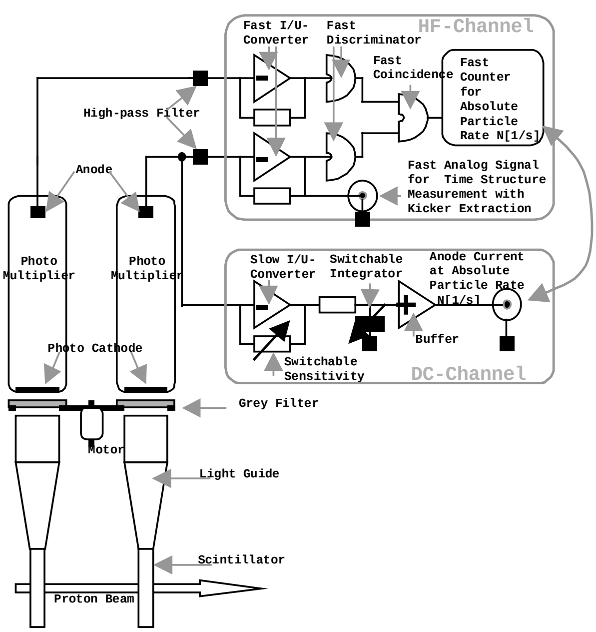

Figure 2: Schematic circuit diagram of the spill detector.

If kicker extraction is optionally performed the synchrotron is emptied within a fraction of a micro second and rates of up to 10^{16}/s within one short pulse may occur. There is no detector available which can directly measure absolute rates over such a wide range of intensity. The most frequently used detectors for absolute rate measurements are:

a) Ionisation chambers, which measure properly only with medium rates. At high pulse currents in the case of kicker extraction unknown pair recombination may disturb the measurement.

b) Photo multipliers with different scintillators, which measure properly by single event counting at small rates. Even with a short dead time of 20 ns the limit rate is < 10^6/s as a precise dead time correction is not possible.

We have found a procedure for the type b) detector by which absolute rate measurements can be extended to the huge range mentioned above. It consists of two parts (Fig. 2):

a) At low count rates <10^6/s the total number of protons during one extraction cycle time is counted absolutely while the anode current of the photomultiplier is integrated by a precise I/U-converter simultaneously. Thus the relative anode current (gain of the multiplier and scintillator efficiency are only roughly known) is related to an absolute but low count rate. For the higher count rates we use the fact that the anode current increases linearly for further four decades with the count rate if the voltage divider is designed properly. Thus count rates up to 10^{10}/s can be measured absolutely within some percent.

b) There is a gap of 2 mm between light guide and multiplier cathode into which a grey filter with high light attenuation of up to 10^5 can be moved in and out by remote control. Then even the integral charge of pulses from kicker extraction can be measured absolutely with sufficient precision. The light attenuation itself can be measured on-line. At a higher rate of about 10^8/s at stochastic extraction, which is already calibrated without light attenuation and should be stable during some seconds, the grey filter is moved into the gap reducing the rate according to the actual filter attenuation.

3 MEASUREMENTS

First experiments at 180 MeV showed a pulse of the extracted proton beam with width (FWHM) of some 100 ns and intensity of $3{\cdot}10^7$ protons. As evidence for the fast beam extraction Fig. 3 shows the WCM-signal and the signal from a scintillator in the extraction beamline, but this taken out of beam. Furthermore the kicker signal and the Σ-signal of a beam position monitor (BPM) in the ring are displayed. The latter one clearly shows the sudden decrease of the internal beam caused by the fast extraction. Fig. 4 demonstrates the importance of beam cooling for the effective fast beam extraction.

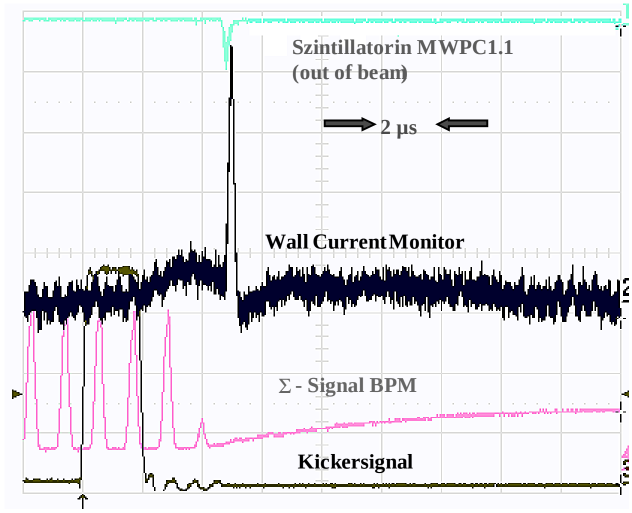

Figure 3: Fast kicker extraction at 600 MeV/c. For details see the text. The time differences between the signals are due to different particle travelling times and non-calibrated cable lengths.

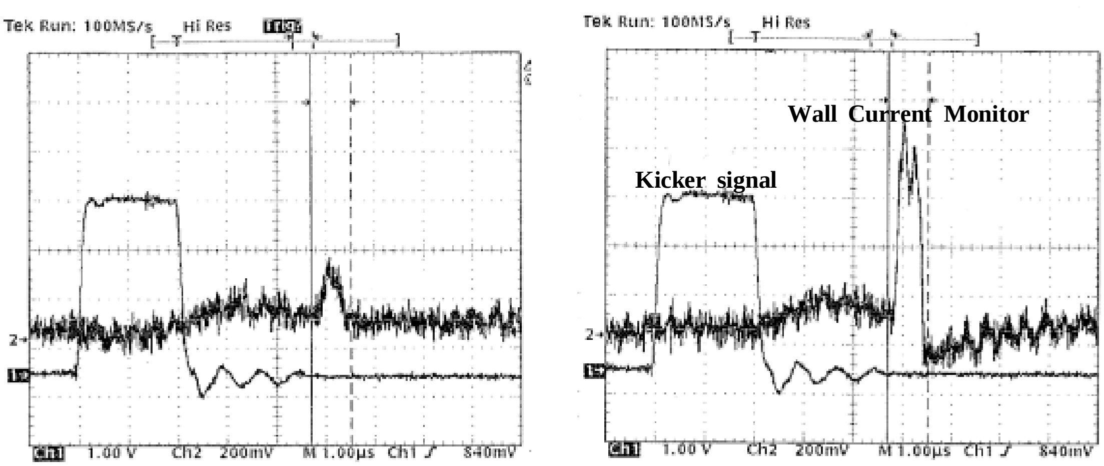

Figure 4: Fast kicker extraction with (right) and without (left) electron cooling at injection energy and following acceleration to 180 MeV. For the time difference between the signals see Fig 3.

In the next time the fast kick process must be investigated in the whole energy range of COSY and the process must be optimized to enhance the intensity of the kicked proton pulse.

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