Linac4 Beam Coordination Committee - Meeting 2 held on 16 June 2009

Present: Oliver Aberle; Philippe Baudrenghien; Giulia Bellodi; Alfred Blas; Jan Borburgh; Christian Carli; Rocio Chamizo; Alan Findlay; Frank Gerigk; Brennan Goddard; Klaus Hanke; Thomas Hermanns; Mark Jones; Yacine Kadi; Alessandra Lombardi; Roberto Losito; Remo Maccaferri; Stephan Maury; Bettina Mikulec; David Nisbet; Mauro Paoluzzi; Flemming Pedersen; Uli Raich; Suitbert Ramberger; Roberto Rocca; Carlo Rossi; Marco Silari; Maurizio Vretenar.

1. Minutes of the last meeting

The minutes of the last meeting have been approved with the following addition:

Action: For clarity with respect to the presentation on the "Status and test programme of the ion source" in the last meeting, the BCC requests to supply a schedule on the source commissioning and production of beam, and to present it at one of the forthcoming BCC meetings until September **(D. Küchler).**

2. Introduction to this meeting on the head dump (C. Carli)

In the current scenario, a significant amount of beam is sent on a head dump, which is integrated inside the BI.SMV tank: (i) 40 ns of 65 mA beam every 1 µs during the build up of the LEBT space charge compensations due to a chopper limitation, and (ii) 60 µs of beam with an average current of 40 mA for stabilization of the RF system (compensation of the transient beam loading via feedback loop). Furthermore, 40 ns pulses of 65 mA beam every 1 µs during 20 µs needed to stop the source due to the chopper limitation have to be sent to the tail dump, which is installed in the BI.SMV tank as well. First FLUKA simulations gave very high inacceptable activation levels of these dumps. Even the small amount of beam hitting the tail dump is a concern.

Several questions and ideas were brought up in a first discussion on March (see: http://cern.ch/carli/PSBwithLinac4/Meeting09_03_19/Minutes09_03_19.html) and will be followed up and discussed in this meeting. How do activation levels at 160 MeV compare to the current situation of 50 MeV, is a beam head really required, does a chopper or pre-chopper upgrade improve the situation?

3. Comparative simulations of beam impact at 50 MeV and 160 MeV on a beam dump (R. Rocca)

Fluka simulations on energy deposition and on residual and absorbed dose rates of different materials for the head dump have been undertaken. In the current design, the head and tail dumps are internal to the magnetic septum tank as is the case for the existing Linac2 version. In the simulations on activation, 60 µs per pulse of a beam linearly rising to 40 mA have been assumed.

In a failure scenario for the distributor, one full beam pulse of 400 µs would impinge on the head dump. Taking the correct beam shape into account, longitudinal profiles of maximum temperatures in cross-sections along the head dump have been simulated. The worst case was found for copper leading to temperatures above the melting point. The thermal diffusion time is much longer than the beam duration. Likewise aluminium has to be excluded. AlN would be a possible material but even better results were achieved with Graphite and boron-nitride (BN). Tungsten has not yet been included in this simulation.

For residual dose rates, an irradiation over 200 days of operation with a chopped beam of 60 µs and a cool-down time of 1 week has been assumed. Residual dose rates in the order of 100 mSv inside the tank have been found which would make interventions on the septum impossible. Compared to an operation at 50 MeV like in Linac2, at 160 MeV the activation per proton increases 8 fold and is dominated by nuclear interactions. The ambient equivalent dose rates at 160 MeV outside the tank would reach around 2-13 mSv/h.

Simulations with a BN dump material with tungsten shielding, the absorbed dose on the septum reaches up to 6 MGy/yr. These numbers indicate issues for the maintenance as well as for the lifetime of the magnets. The issue is that not much further shielding could be installed to change this situation.

3.1. Discussion

M. Vretenar raises the question by how much the dose rates would have to be reduced in order to be able to keep the dump inside the septum tank.

M. Silari responds that it is a different issue if the tank remains closed or if interventions on the tank are required. For example, there have never been interventions on the BISMV in the current Linac2 configuration.

J. Borburgh remarks that other septum tanks exist which operated without interventions for years and one day had to be opened. Building full spare septum tanks would be expensive. If the dump could be moved outside it could be shielded like the Linac4 main dump.

M. Silari reminds that the head dump in the current scenario needs to be dimensioned for the same amount of beam as the Linac4 main dump where it is possible to shield. He adds that acceptable dose limits also depend on the work to be done: Small objects that are handled remotely may have a higher dose. A remotely handled plug-in dump could help in case of an intervention but it would not reduce dose rates outside the closed tank as the issue there is the missing shielding.

Y. Kadi remarks that moving the dump outside has not been investigated so far.

4. Performance of the low level RF system for compensating chopping (P. Baudrenghien)

The current design for the low level RF system foresees a feedback loop in order to compensate for transients. The loop delay of 1.1 µs is dominated by the contribution of the cable lengths defined by the location of the Faraday cage with respect to the accelerating structures. The closed loop bandwidth thus is found as 300 kHz. Scaling from experience with the LHC feedback system, it is expected that the feedback is efficient to compensate 10 µs long pulses.

Concerning beam induced transients, the beam cannot create sharp beam loading pulses because of the limited cavity bandwidth. If the klystron reproduces the transient at its output, a perfect compensation of transients can be achieved. Therefore a feedforward system is required. The klystron bandwidth of both, the LEP klystrons and the new 2.8 MW klystrons is > 3 MHz. Simulations suggest that the klystrons are capable to limit the perturbation in cavity voltage to < 0.5 % by reducing the klystron drive. The chopping pattern must be synchronized with the feedforward.

In order to properly compensate pulse current amplitudes, the compensation pulse needs to be adjusted by a pick-up signal. After about 5 µs the feedback would kick in and regulate transients e.g. from the klystron modulators. The system would not need any training for known beam currents. The beam chopping signals beam on and beam off would be used to initiate the feedforward. For this to work, the low level RF systems must be in charge of creating the chopper signals.

The SNS experience shows that such a system is feasible and that there is no head or tail beam that would have to be dumped. The same should be true for Linac4. SNS however uses a pre-chopper and a fast chopper in their configuration.

4.1. Discussion

M. Vretenar proposes to test the low level RF system on the test stand using the two buncher cavities for beam acceleration as the DTL1 tank will not be available with beam on the 3 MeV test stand following an earlier decision.

M. Vretenar summarized that no beam should be seen on the head or tail dumps except in the case of equipment failure and beams would be set up using the main dump. Y. Kadi comments that in this case the dumps would become protection devices and their design might look quite different. Still the thermo-mechanical issue for a full beam pulse would remain valid.

P Baudrenghien wonders about transients in multi-cell cavities. F. Gerigk considers these transients as negligible.

5. Status and upgrade options for the 3 MeV chopper (M. Paoluzzi)

The linac4 bunches are 0.84 ns in length with a spacing of 2 ns between bunches corresponding to the RF frequency of 352.2 MHz. t_{on} and t_{off} times consisting of chopper rise and fall times, jitter, delay and pulse length variations have thus to be < 2 ns, < 4.8 ns or < 7.6 ns in order to have at maximum 0, 1, or 2 deflected bunches respectively. The baseline for Linac4 operation is that disturbing 1 bunch is acceptable.

Currently 2 drivers are available at CERN. The first type is a commercial system that fulfills the specification in all points except for the maximum pulse length, which is limited to 1 µs. This limit is due to a physical limitation in the devices and nothing can be done about this limit. The t_{on} and t_{off} times are both below 4.8 ns. 3 units of each of each polarity plus spares are available at CERN. The second type was made at CERN and is slightly worse in all parameters than the commercial system except that it can generate the required pulse length of up to 100 µs. In particular the t_{on} and t_{off} times are slightly above the 4.8 ns such that two bunches would be deflected. 2 units of each polarity plus spares are available at CERN.

Both systems are incompatible with the LPSPL chopping frequency of 40-50 MHz, which is why a new development is on-going with a modular approach. This design requires further work and funding of 30-50 kCHF over the next few years.

5.1. Discussion

A. Lombardi explains that the partly deflected bunches are transmitted and would probably arrive at the PS-booster. One of the reasons is that these bunches have no space charge and are therefore not lost in the Linac. She wonders why it would not be acceptable to disturb 2 pulses.

Action: Study where unchopped bunches will be exactly lost and provide phase space plots. **(A. Lombardi)**

M. Vretenar would like to know which one is the most reliable design. M. Paoluzzi comments that there have been no failures during tests on either system, however the commercial proprietary design cannot be repaired at CERN and the chip would have to be sent to the manufacturer. The CERN system consists of standard parts that are relatively cheap and are easy to maintain. There is no experience on the newer development for the LPSPL so far.

C. Carli comments that they had planned to use additional off pulses for a reduction of the average current in the PSB. It turns out that this scheme would probably not work. A. Lombardi comments that she has an alternative scheme acting on the transmission at low energy that would be able to achieve this.

S. Maury proposes that the development on the 50 MHz chopper driver continues but in case it would not be ready for Linac4 start-up, the CERN driver should be used.

M. Vretenar requests to have a scenario for a chopper failure. F. Gerigk comments that in case of failure, the cavities would receive an unchopped beam, which they would not be able to accelerate because of insufficient power. Interlocks should kick in after about 10-20 μs.

P. Baudrenghien proposes raising the average beam current linearly over the first few microseconds by decreasing progressively the chopping rate, as is done at SNS. This could ease the task for the low level RF and help reducing residual beam loading transients at the beginning of the Linac4 beam pulse.

6. AOB

No AOB.

Suitbert Ramberger

Next meeting: Tuesday 25 August, 9:00, room 354 1-001