SUMMARY OF WORKING GROUP 3: ASSESSMENT OF THE WIRE LENS SCHEME AT LHC FROM THE CURRENT PULSED POWER TECHNOLOGY POINT OF VIEW

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Abstract

Working group 3 of the RPIA 2006 workshop addressed the technical realization of a pulsed wire-lens beam-beam compensator at the LHC. For one of two proposed approaches, namely a piecewise linear one based on switches, a preliminary design was sketched and its critical issues were identified.

INTRODUCTION

The seven participants of Working Group 3 are listed as authors. The working group was convened by Edward Cook of LLNL and Frank Zimmermann of CERN. Edward Cook and Kota Torikai of KEK spearheaded the discussion and proposed two alternative approaches towards a technical solution for a pulsed long-range beam-beam compensator at LHC.

REQUIREMENTS

In first approximation the wire of the proposed compensator [1] can be modelled as a pure inductive load [2].

The wire pulse pattern should mimic the LHC bunch train pattern, as is illustrated in Figs. 1 and 2. Figure 3 shows a zoomed view of the wire excitation pattern. It should be possible to smoothly scale the wire-current amplitude on the time scale of hours, so as to follow the decreasing beam currents.

A cost-effective solution for the pulsed system is looked for.

The parameters of the desired wire-lens compensator [3, 4] are summarized in Table 1. The challenging issues are the high repetition rate, and the turn-to-turn stability tolerances (highlighted in bold).

ISSUES

The working group discussed the following open issues and questions:

- is such pulser feasible? (clearly we hope that the answer is ‘yes’);
- which technology could be used?
- is this type of pulser perhaps already commercially available?

Table 1: Parameters of the LHC pulsed beam-beam compensator

revolution period (pattern repetition)	88.9 μs ± 0.0002 μs (variation with beam energy)
maximum strength	120 Am
maximum current	60–120 A (depending on length)
ramp-up/down time	374.25 ns
length of maximum excitation	1422.15 ns
length of minimum excitation (larger times could be needed)	573.85 ns & 598.8 ns
length of abort gap (may vary)	2594.75 ns
number of pulses per cycle	39
average pulse rate	**439 kHz**
pulse accuracy w.r.t. ideal	5%
turn-to-turn amplitude stability (relative to peak)	10^{-4}
turn-to-turn timing stability	**0.04 ns**

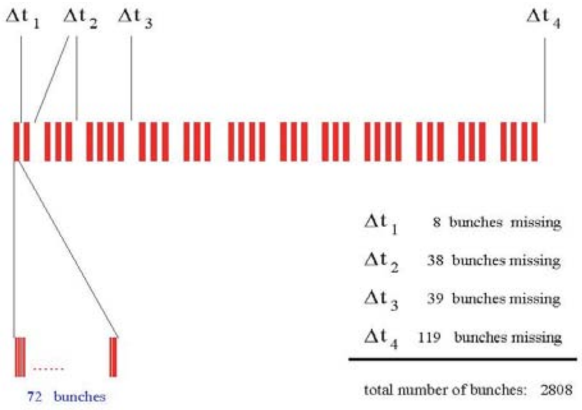

Figure 1: The nominal LHC bunch filling pattern [5], with a basic bunch spacing of 25 ns.

- distance between pulser and wire (are 50 m or 200 m acceptable?); here, the issues are cable impedance and reflections which consume power and may distort the excitation pattern;
- radiation hardness;
- electromagnetic compatibility (LHC EMC police);

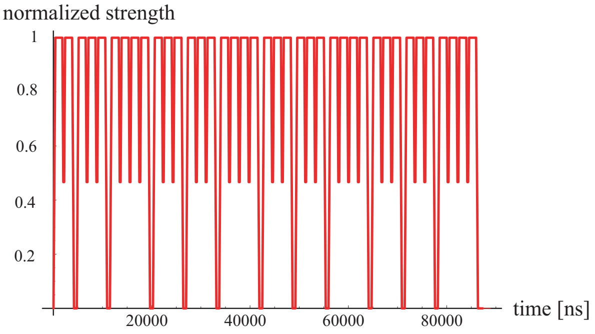

Figure 2: The excitation pattern of the pulsed compensator corresponding to the nominal LHC bunch filling scheme in Fig. 1, as a function of time. The signal is normalized to the maximum amplitude.

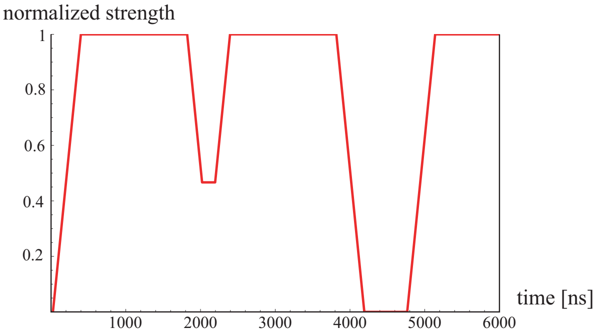

Figure 3: Zoomed view of the wire excitation pattern in Fig. 2.

- termination and cable impedance (e.g., 50 Ω, few Ω, mΩ?);
- rough cost estimate (some M$?, 100k$?);
- circuit architecture and prototype;
- laboratory tests?
- RHIC machine studies in 2007/08?
- do we use only the *B* field as planned, or would a combination of *E* and *B* fields like in a stripline kicker be preferred?

Figure 4 shows a photo of the working group activity.

DISCUSSION RESULTS

In the course of the discussion, Edward Cook proposed a piecewise linear approach and sketched a possible circuit diagram of a switching device which could generate the desired pulse shape. A chalk drawing of Ed's layout is displayed in Fig. 5, and the equivalent circuit programmed by Ulrich Dorda using SPICE [6] in Fig. 6. The inductance of the wire lens has been estimated by F. Caspers to be of the order of 0.5 μH. The characteristic impedance of the feeding cable is thought to be about 50 mΩ if the pulser is installed close to the wire, or 2 Ω if it is installed upstairs. The wire capacitance is insignificant. The slope of the linear wire-current increase is defined by the voltage applied to the inductive load of the wire.

Figure 4: Working group members during discussions in front of a blackboard.

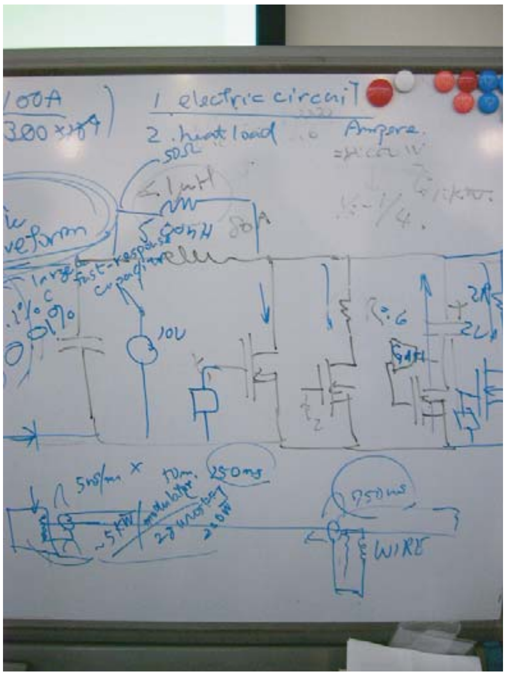

Figure 5: Circuit layout developed on the blackboard.

This device consists of 4 MOSFET switches which are commercially available (e.g., APT 60M75L2LL), two or three power supplies with a stability of 10^{-4}, 2 resistors, and 1 or 2 capacitors. It is switched using an arbitrary wave form generator with multiple outputs. The cost is estimated to be rather low (all component prices lie in the range of a few 1000s of dollars).

The timing jitter may or may not be a problem. If it turns out to be an issue, a possible remedy might be creating a "step-like" pulse shape [7] instead of a linear rise or decrease, so that the deflecting field during the passage of

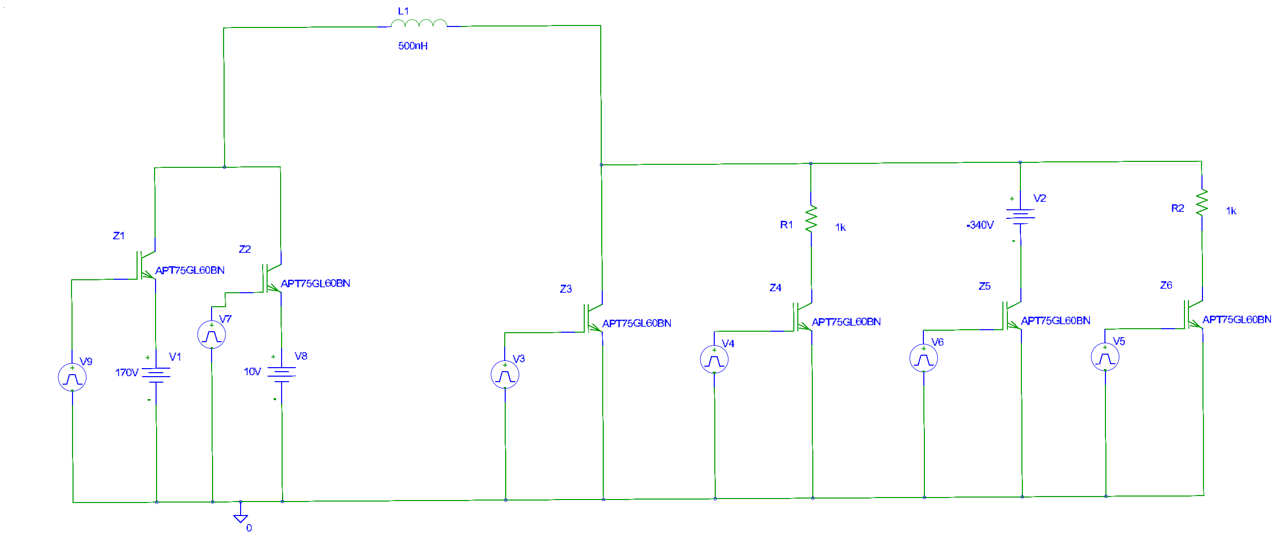

Figure 6: Circuit diagram in SPICE [7].

a bunch is insensitive to timing jitter. The decreased sensitivity comes at the expense of introducing higher excitation frequencies.

Radiation hardness is an issue, if the pulser is to be installed close to the beam pipe. Radiation hardness depends on the type of switching element. SiC-MOSFETs for example are more resistant than standard MOSFETs. However, if the switching elements eventually selected should turn out to be not sufficiently radiation hard, the activation inside the LHC tunnel may require placing the pulser at a distance of about 200 m from the wire lens itself. In this case, the properties of the low-impedance cable feeding the wire must be taken into account when computing the pulse form of the switch (which has not been done for Figs. 5 and 6). The importance of transmission-line effects was judged differently by the participants. It was finally agreed that these effects need special attention and may require significant adaptations of the design.

It is planned to build a fast-switch prototype at CERN, and to verify its timing stability. In addition, beam tests with a pulsed wire compensator are foreseen in RHIC from 2008 onwards as part of the US LARP activity.

Kota Torikai pointed out an alternative design approach which would implement the pulser as a wide-band rf system. Such scheme would imply more heating and the use of a larger number of MOSFETs, mounted serially or in parallel.

The jitter stability of the reference timing signals in the LHC and in RHIC is to be verified [9]. If it turns out to be insufficient, a dedicated beam signal generated from a nearby pickup could be an option.

CONCLUSIONS

Working group 3 has considered two different design approaches for a pulsed wire-lens, one based on fast switches, the other on wide-band rf. The former is more economical, but the second would offer greater flexibility for the signal shape. Following the first approach, a piecewise linear pulser using fast MOSFET switches was discussed in a little greater detail, including its design principles and working mechanism. Several critical issues were identified.

ACKNOWLEDGEMENTS

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