

Simulations for the LEReC fast closing valves

B. Xiao

October 2018

Collider Accelerator Department
Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC), Nuclear Physics (NP) (SC-26)

Notice: This technical note has been authored by employees of Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the U.S. Department of Energy. The publisher by accepting the technical note for publication acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this technical note, or allow others to do so, for United States Government purposes.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Simulations for the LEReC fast closing valves

Binping Xiao

9 MHz: the harmonic number h at 120 of RHIC revolution frequency, ranging from 9.104 MHz to 9.256 MHz in LEReC.

Micro-bunch: one 24 mm “flat-top” 100 pC electron bunch.

Macro-bunch: 30 micro-bunch in a row, with 1.42 nS space in between, with the rest empty in one 9 MHz.

1, Motivation

To protect the 704 MHz SRF booster cavity from the possible vacuum activities downstream, a fast closing valve is considered to be installed after the booster cavity and the 2.1 GHz Cu cavity. The LEReC project requires a minimum beam pipe inner diameter (ID) of 60 mm. In this paper, two valves are considered: a 164 mm ID flapper valve that is in stock at BNL, and a 63 mm ID gate valve that can be purchased from VAT. Figure 1 shows these two valves.

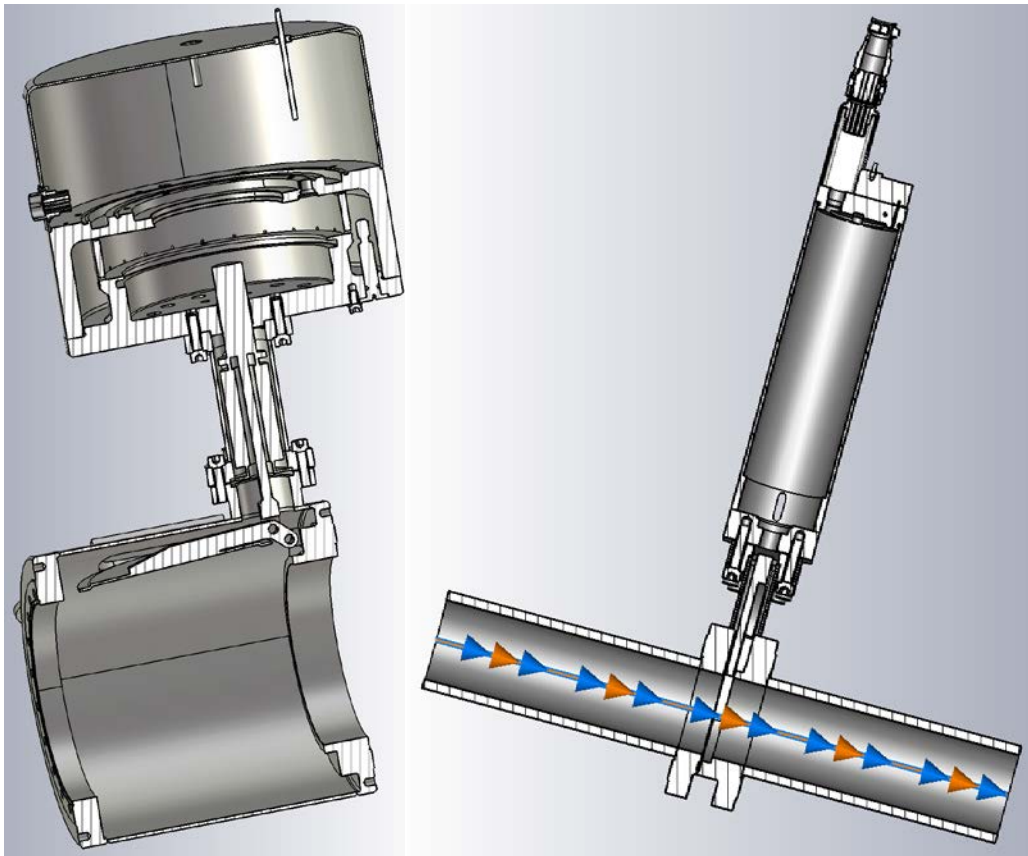


Figure 1. Cross section of the (left) flapper valve, and (right) gate valve.

2, Simulation

To get the desired 24 mm “flat-top” line density distribution, 32 Gaussian laser pulses, with 0.6 mm rms length and 0.75mm spacing, are stacked together[1]. In a previous paper, the difference in the energy spread factor (ESF) between this “flat-top” and a 1 cm rms Gaussian bunch case was calculated [2]. A conclusion from that paper is that using the 1 cm rms Gaussian distribution with beam at speed of light, the peak-to-peak ESF directly retrieved from the peak-to-peak wake potential is higher than the rms ESF (times $\sqrt{2}$ factor) from the “flat-top” distribution. In this paper, we use a 1 cm rms bunch, a 100 m wake length, and 2.5 million to 6 million mesh cells in the CST particle studio simulation. Simulation results are shown in Figure 2. For the flapper valve, on each side of the beam pipe port, there is a 0.5 m long taper to reduce the ID to 60.325 mm.

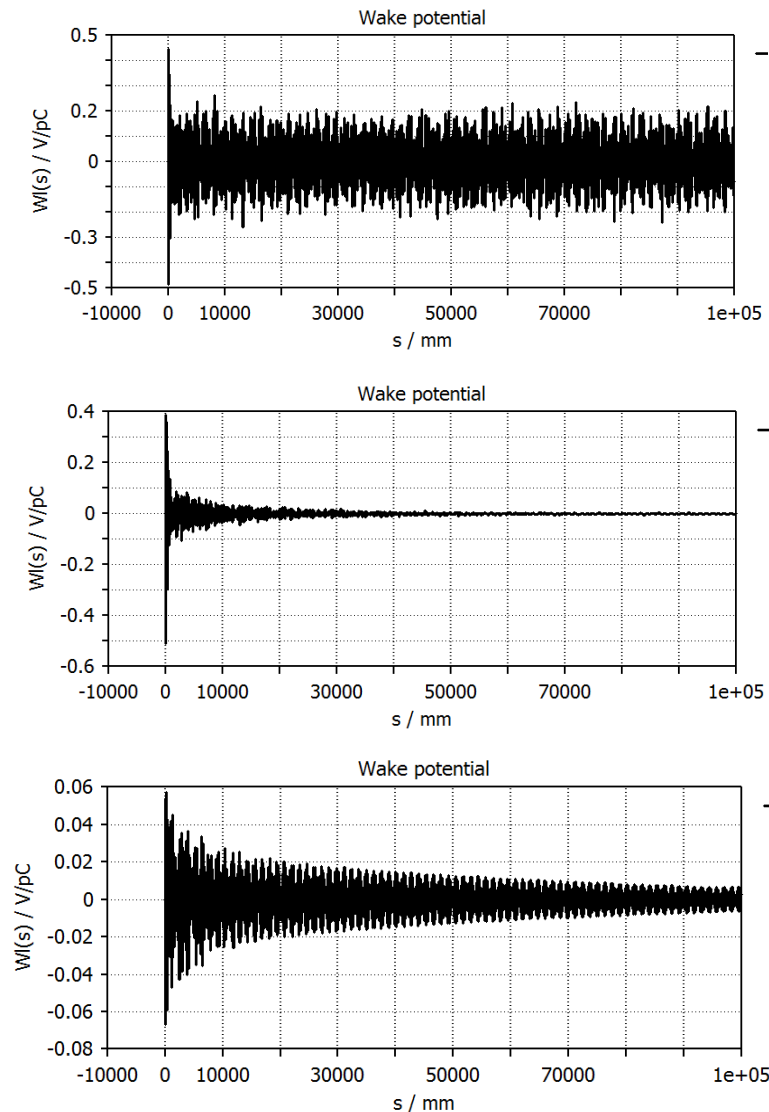


Figure 2. Longitudinal wake potential, from top to bottom: (a) flapper valve without ferrite; (b) flapper valve with ferrite; and (c) gate valve without ferrite.

As we expected, adding ferrite will not reduce the short-range wake potential, instead, the long-range wake potential gets damped quicker with ferrite, since ferrite reduces the quality factor Q , but not the

R/Q. The short-range peak-to-peak momentum spread dp/p for flapper valve is ± 0.510 V/pc, and for gate valve it is ± 0.058 V/pc.

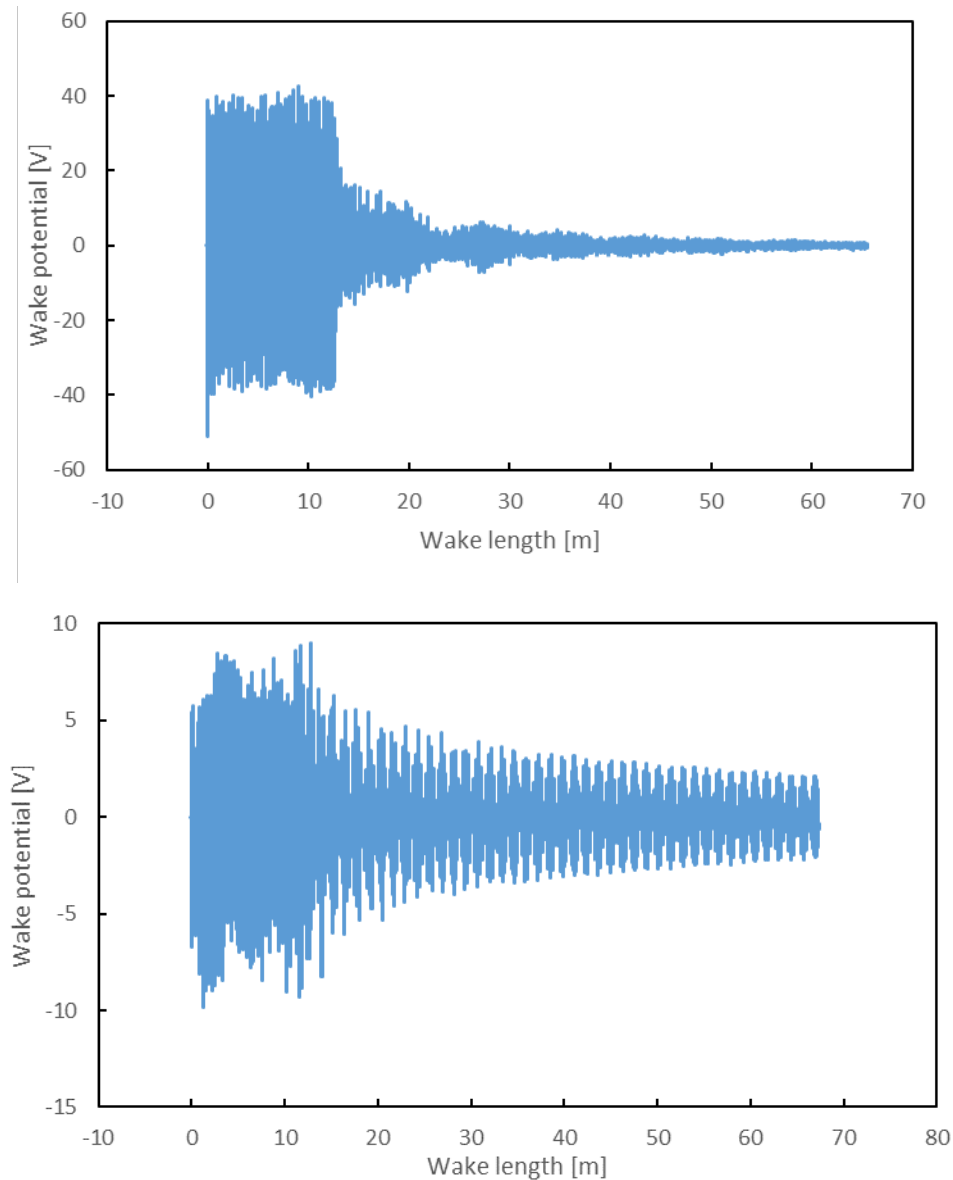


Figure 3. Wake potential in volts (for 100 pC per micro-bunch) with one macro-bunch for (top) flapper valve with ferrite, and (bottom) gate valve without ferrite.

Figure 2(a) shows that there are modes that are not damped well even with 100 m wake length in the flapper valve. These modes have high Q that will affect the next macro-bunch (9 MHz bunch train). If one of these modes has a resonant frequency that happens to be multiple of 9 MHz, the long-range wake potential will cause a voltage fluctuation that might not be tolerable. In this case a 199.25 mm x 64 mm x 29 mm CMD5005 ferrite is added on the bottom of the valve chamber (opposite to the flapper). It helps damping those high Q modes, as shown in Figure 2(b) so that all modes get damped before the next macro-bunch enters the valve chamber. Figure 2(c) shows that in the gate valve, wake potential shows a reasonable decay within 100 m.

The wake potentials in Figure 2(b) and (c) are used to get the responses from one macro-bunch by shifting wake potentials n times 1.42 nS, with n from 0 to 29, and then adding 30 wake potentials together. The results are shown in Figure 3. It suggests that for the flapper valve with ferrite, a ± 51 V peak-to-peak voltage fluctuation will be generated, about 4.5% of the budget. The gate valve without ferrite generates ± 9.8 V, about 0.09% of the budget.

The wake impedance calculated based on wake potentials shown in Figure 2(b) suggests that for the flapper valve, near the multiples of 704 MHz (704, 1408, 2112 MHz), there is no mode with high shunt impedance R , that causes voltage fluctuation enhancement within a macro-bunch.

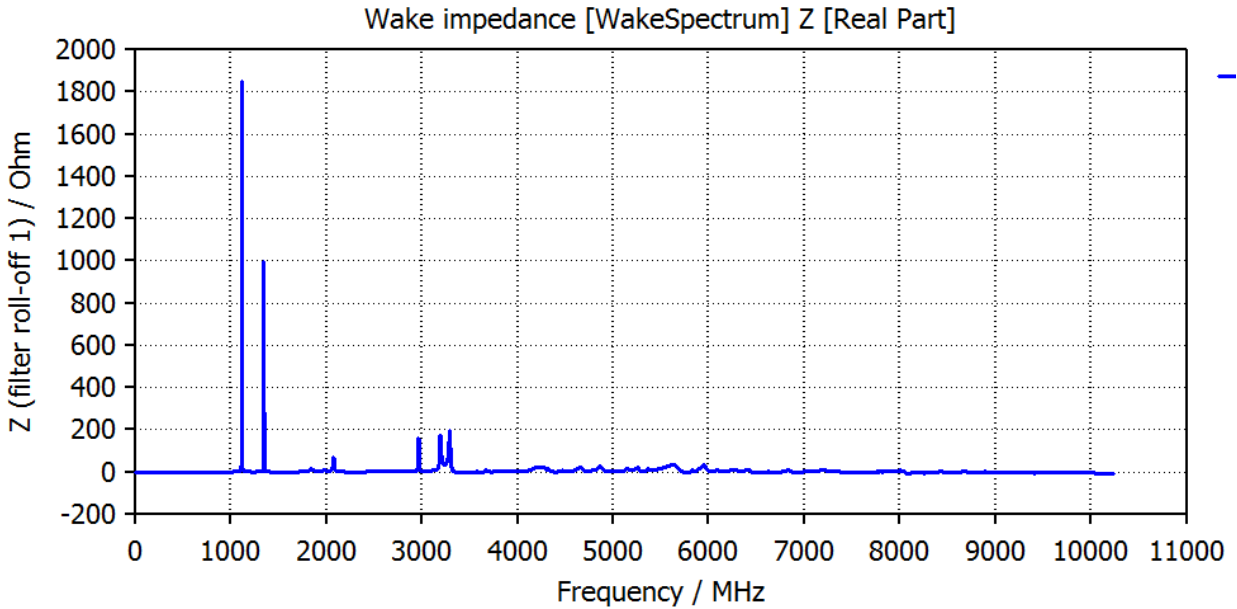


Figure 4. Real part of the longitudinal wake impedance calculated from the longitudinal wake potential of the gate valve without ferrite.

Table 1. Longitudinal modes in the gate valve without ferrite.

Freq [GHz]	Q	R/Q [Ohm]
1.1132	704.56	2.63
1.3446	778.13	1.28
2.0742	132.11	0.52
2.9626	366.66	0.44
3.1892	181.20	0.97
3.2882	161.19	1.22

The real part of the longitudinal wake impedance of the gate valve is shown in Figure 4, with the frequency, Q and R/Q of each longitudinal modes shown in Table 1. The mode at 1345 MHz is 63 MHz away from the multiples of 704 MHz, and the mode at 2074 MHz is 38 MHz away from the multiples of 704 MHz, thus none of the modes is going to resonate with the multiples of 704 MHz. In the worst-case, we assume that each mode has a frequency that is the multiple of 9 MHz. With this worst-case assumption, a train of

macro-bunches will produce ± 12.1 V fluctuation, about 0.11% of the budget. For the CW mode with continuous 704 MHz bunches, the voltage fluctuation will be better than the pulsed mode shown above.

3, Conclusion

With the 164 mm ID flapper valve with ferrite and 0.5 m taper on each side, a ± 51 V peak-to-peak voltage fluctuation will be generated, about 4.5% of the budget. With the gate valve without ferrite, in the worst-case, a ± 12.1 V fluctuation will be generated, about 0.11% of the budget. Gate valve is a better choice while comparing with the flapper valve.

- [1] Z. Zhao, B. Sheehy, M. Minty, *Generation of 180 W average green power from a frequency-doubled picosecond rod fiber amplifier*, Opt. Express **25**, 7, 8138 (2017). <http://www.opticsexpress.org/abstract.cfm?URI=oe-25-7-8138>.
- [2] B. Xiao, M. Blaskiewicz, A. Fedotov, *et al.*, 2018 <https://public.bnl.gov/docs/cad/Documents/Wake%20loss%20and%20energy%20spread%20factor%20of%20the%20LEReC%20Booster%20cavity%20caused%20by%20short%20range%20wake%20field.pdf>.