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AC dipole requirements for beam extinction for the Fermilab Mu2e Experiment

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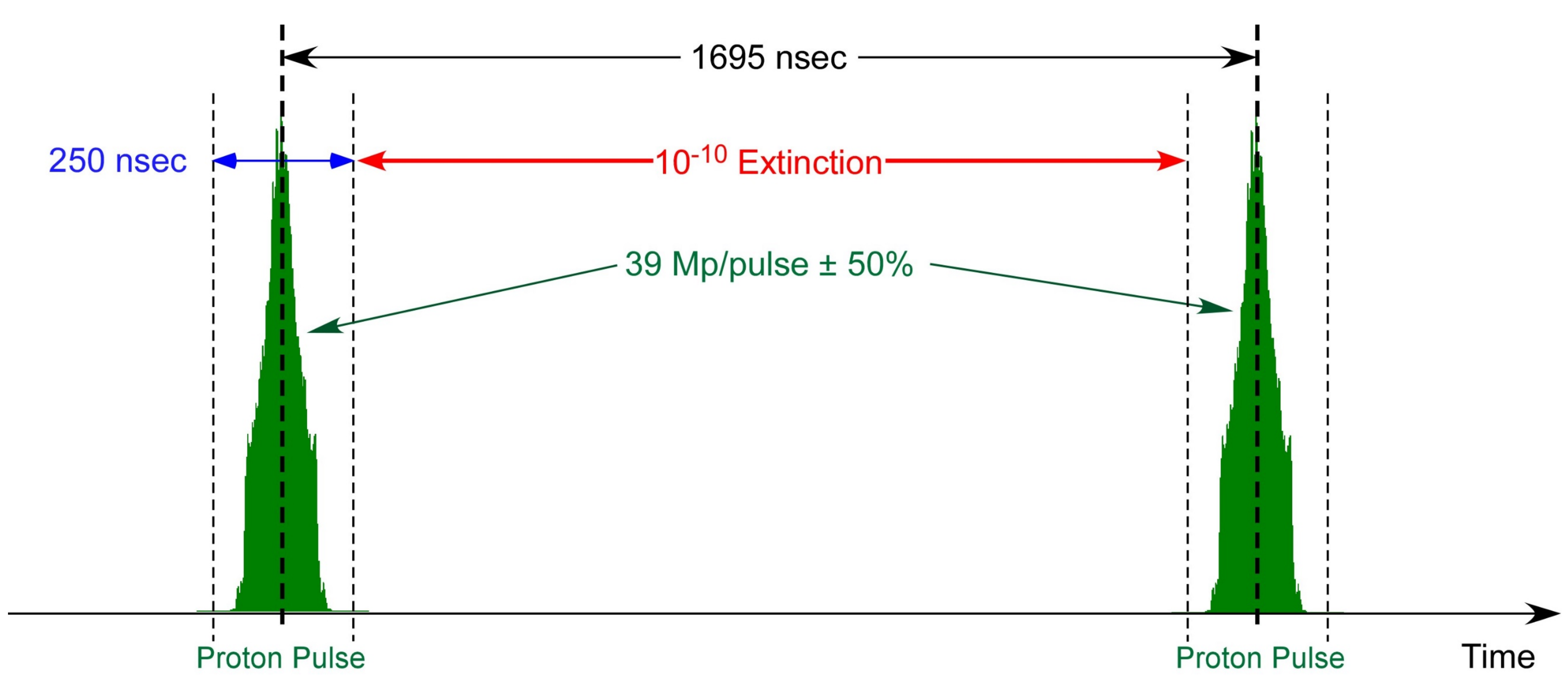
Introduction

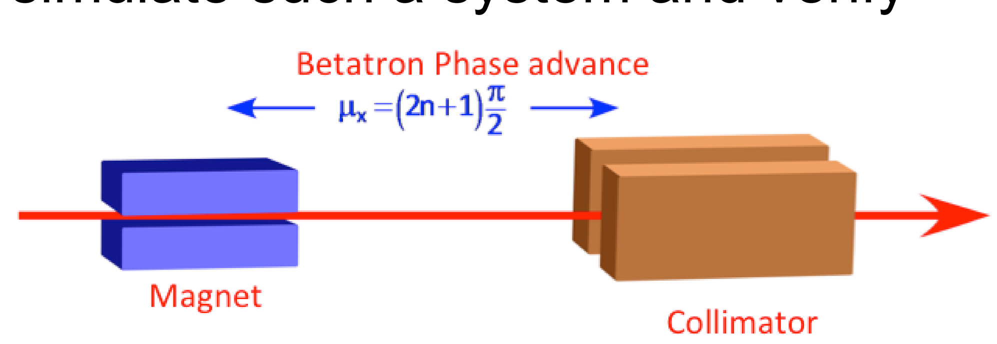
- Mu2e experiment is a particle physics experiment which studies the muon-to-electron conversion without producing neutrinos.
- The experiment has very stringent limits on the amount of the beam that appears between pulses.
- Extinction requirement is < 10^{-10}.

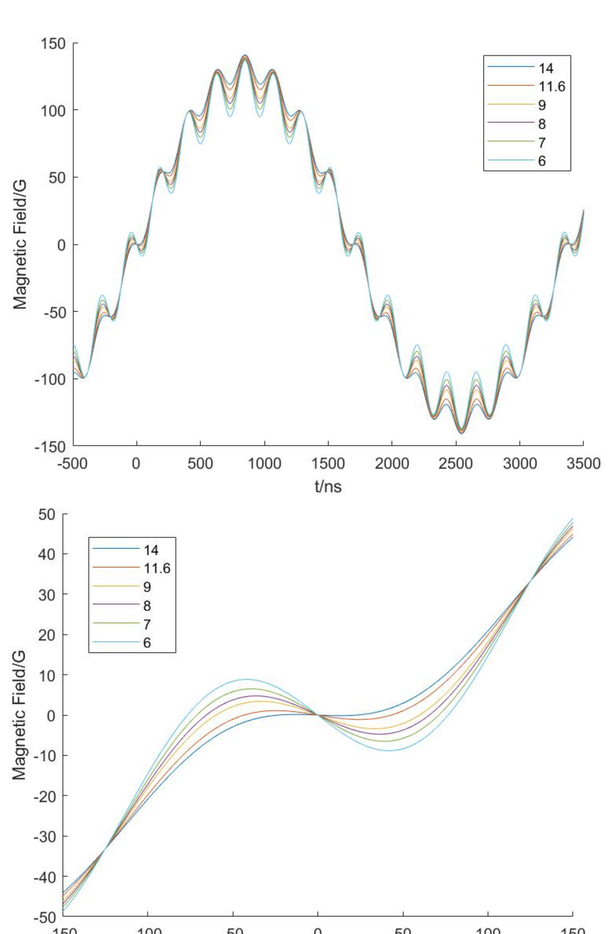


Expected Proton Pulse

Proposed Method

- An "External Extinction System" will consist of a set of resonant dipoles and a collimation system, such that only in time beam will be transmitted to the production target.
- The system will be installed along the M4 line of the Fermilab Muon Campus.
- The aim of this work is to simulate such a system and verify the < 10^{-10} requirement.





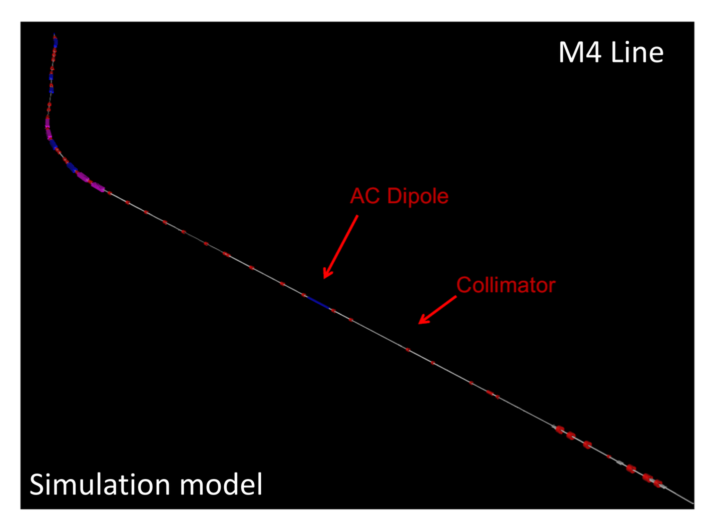
$Ratio$	$B_{0L}(G)$	$B_{0H}(G)$
14.0	131.5	9.4
11.6	129.1	11.1
9.0	125.1	13.9
8.0	123.0	15.4
7.0	120.4	17.2
6.0	117.1	19.5

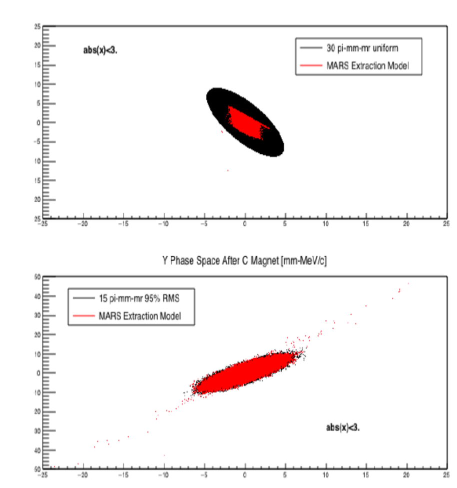
AC Dipole Magnetic Field

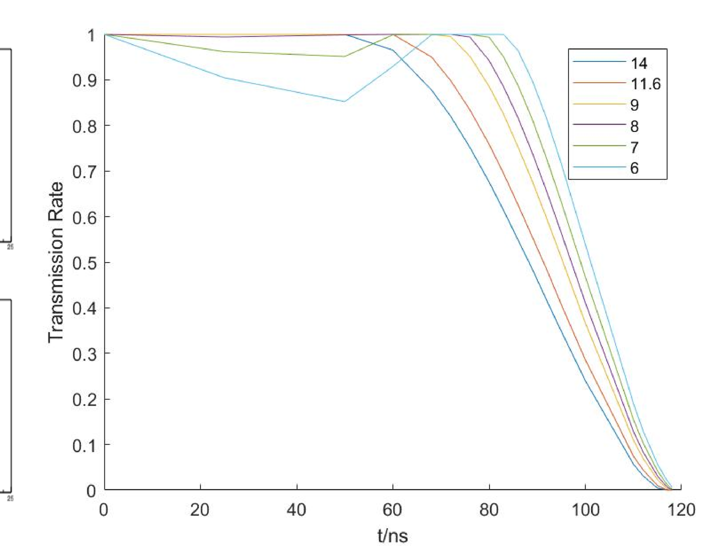
- We are using a combination of two sinusoidal fields. The two frequencies are 300 kHz and 4.5 MHz, which correspond to the 250 ns pulse window and the 1695 ns beam repetition period.
- The required B field at t=0 is about 0.
- We determined the minimum field for extinction to be ± 33 G. As a result, this should be value of the field at ± 125 ns.
- While several waveforms can satisfy this requirement, their shape can vary and is determined by the peak-field ratio between the low and high frequency. We looked at six different cases.

Transmission Studies

- We set-up a G4beamline simulation and examined the influence of the field waveform in the overall transmission.
- We found that the ratio of the peak magnetic field between the low and high frequency has a significant influence on transmission.
- We concluded that a ratio of 9 is best—a lower ratio will create non-zero field near the center of the pulse window, while a higher ratio will make the window narrower than expected.
- All simulations assume a beam with 30 μm full normalized emittance in bend plane and a 15 μm 95% normalized Gaussian emittance in the non-bend plane.

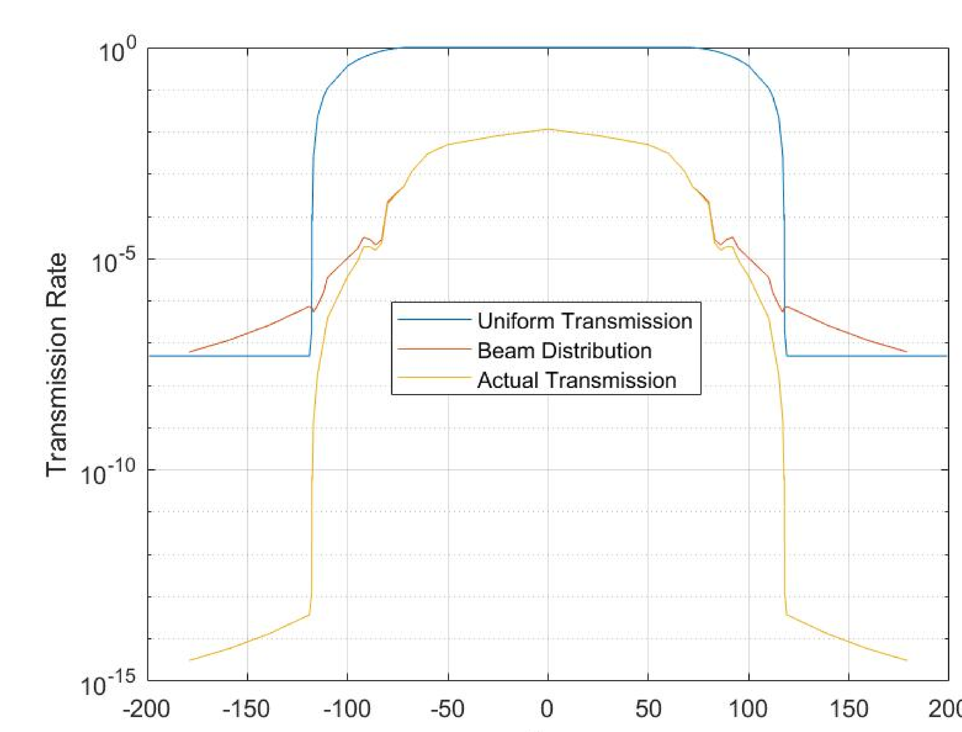






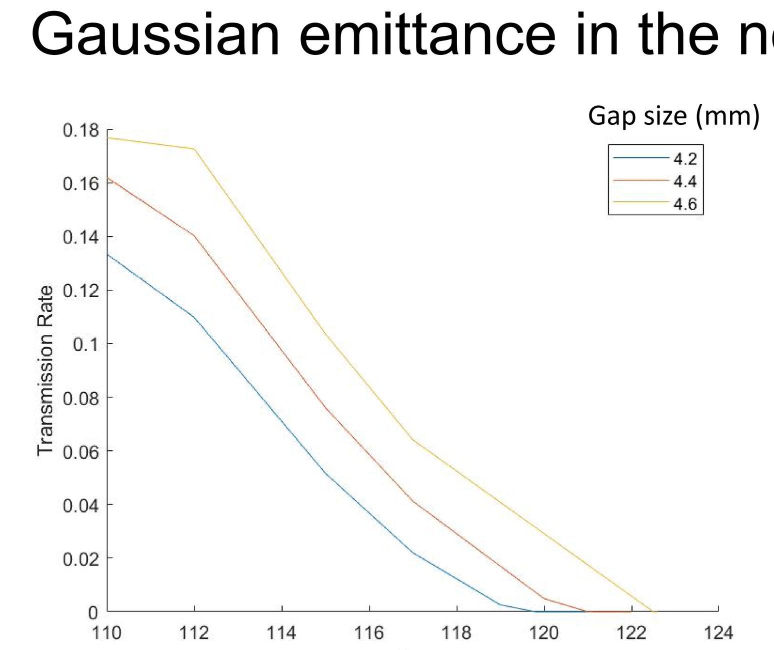
Extinction Performance

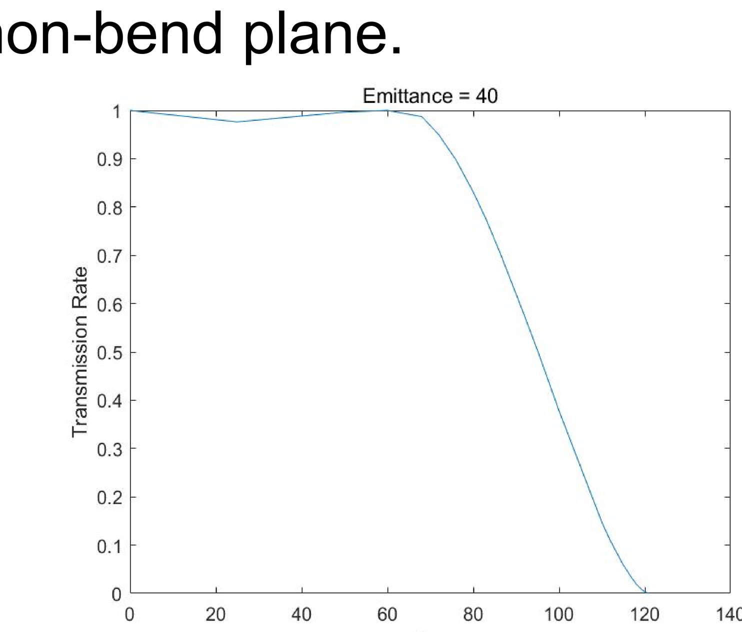
- For ratio 9, we combine its transmission with the expected time profile of the incoming beam.
- We reach a extinction that is much better than the 10^{-10} requirement.
- The transmission is 99.66%



Error Analysis

- For ratio 9, we examined the sensitivity in performance with collimator alignment errors by varying the gap size. The collimator design gap size is ~4.0 mm.
- For ratio 9, we examined the sensitivity to the initial emittance by using a beam with 40 μm full normalized emittance in bend plane and a 15 μm 95% normalized Gaussian emittance in the non-bend plane.





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