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Evaluation of Pulsed Septum Leakage Fields and Compensation for the Advanced Photon Source Upgrade

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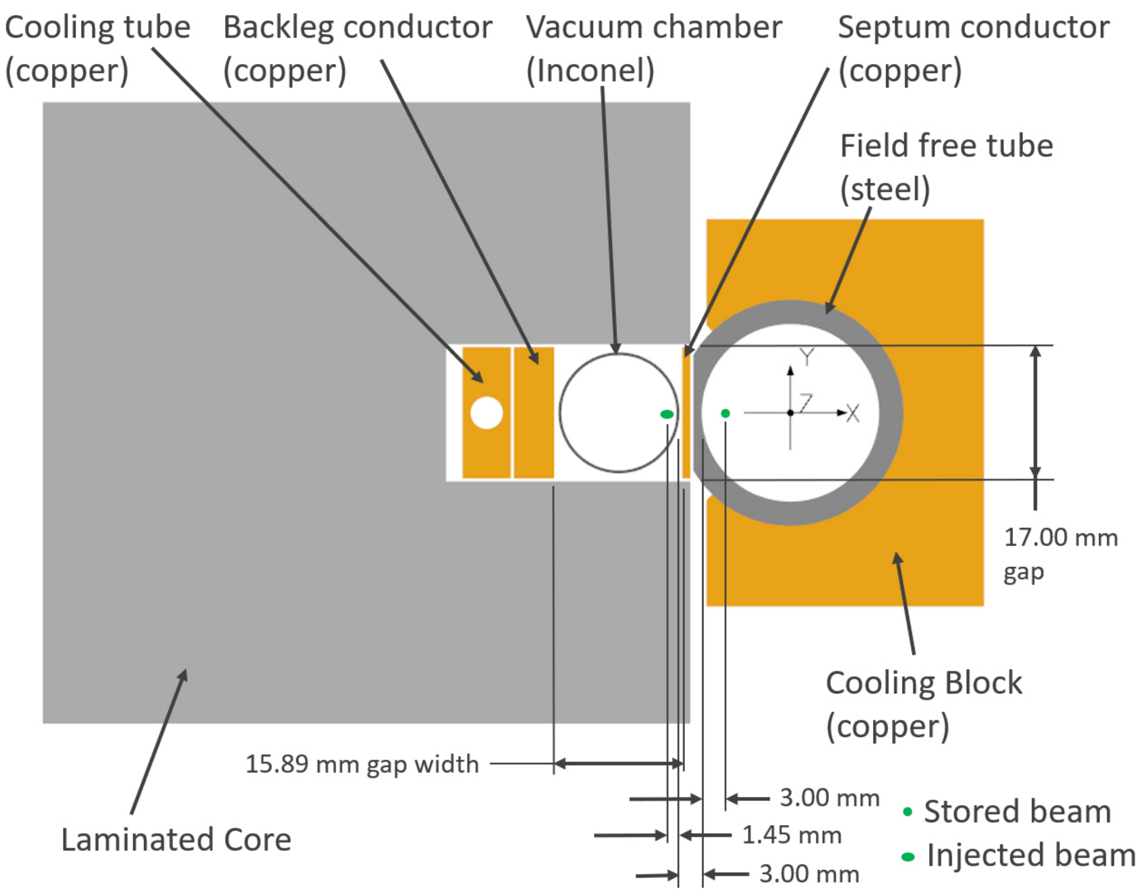
Septum conceptually similar to present APS septum

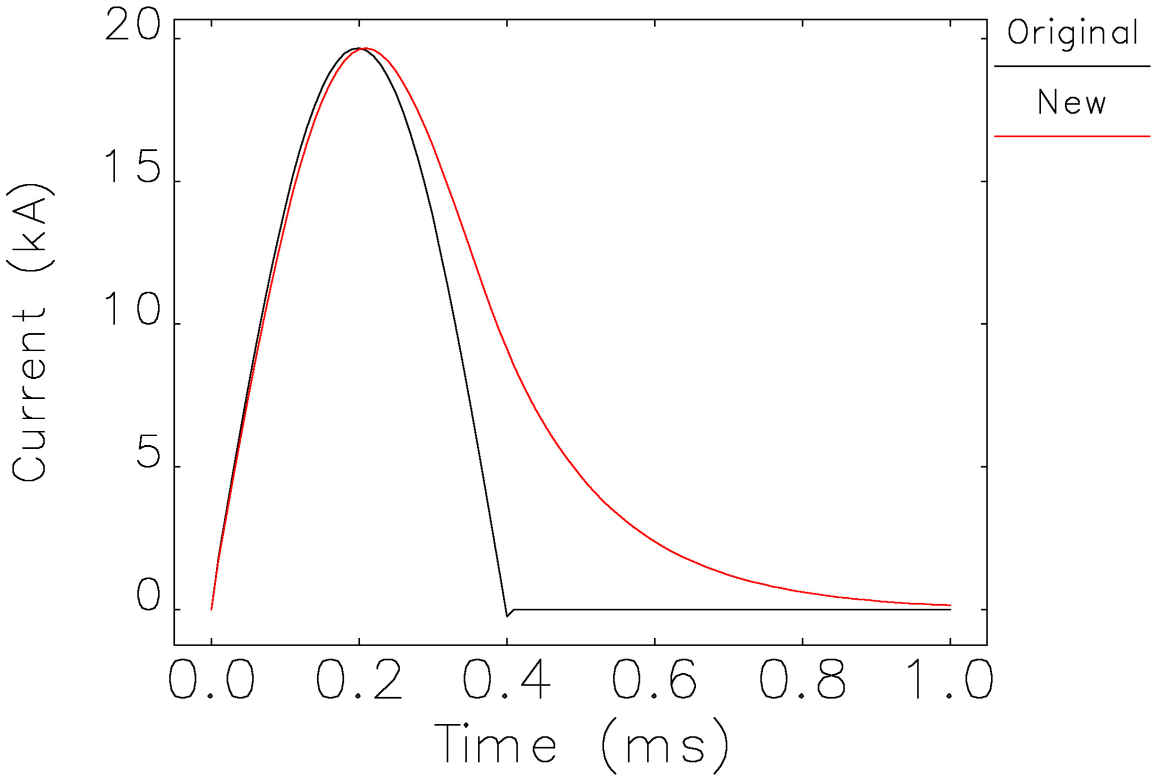
- The APS-U[1] septum uses the same approach as existing APS septum[2]
  - Single-turn
  - Direct-drive
  - Steel shield tube
- Field is 1.42 T (up from 0.72 T)
- Modeling performed on reduced models using OPERA[3]

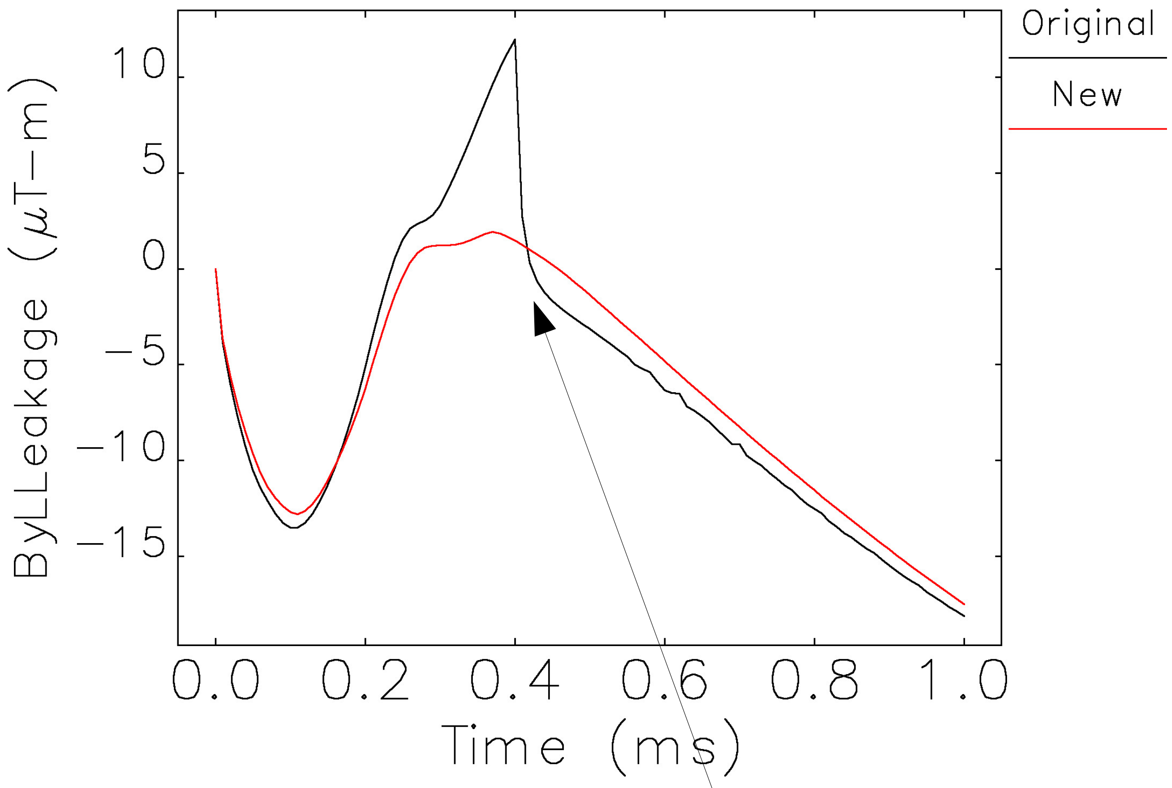


Fast tracking methods provide reliable results

- Requirements for the septum
  - Want beam motion under 10% of beam size
  - Want emittance increase under 2%
- Tracking simulations must include time-dependent leakage kick
  - Varies with turn, bunch number
- Used ILMATRIX (Individualized Linear MATRIX) in **`elegant`**[4,5]
  - Includes tune shifts with momentum, amplitude
  - Accurately models centroid motion, decoherence
  - 10^4 times faster than element-by-element tracking

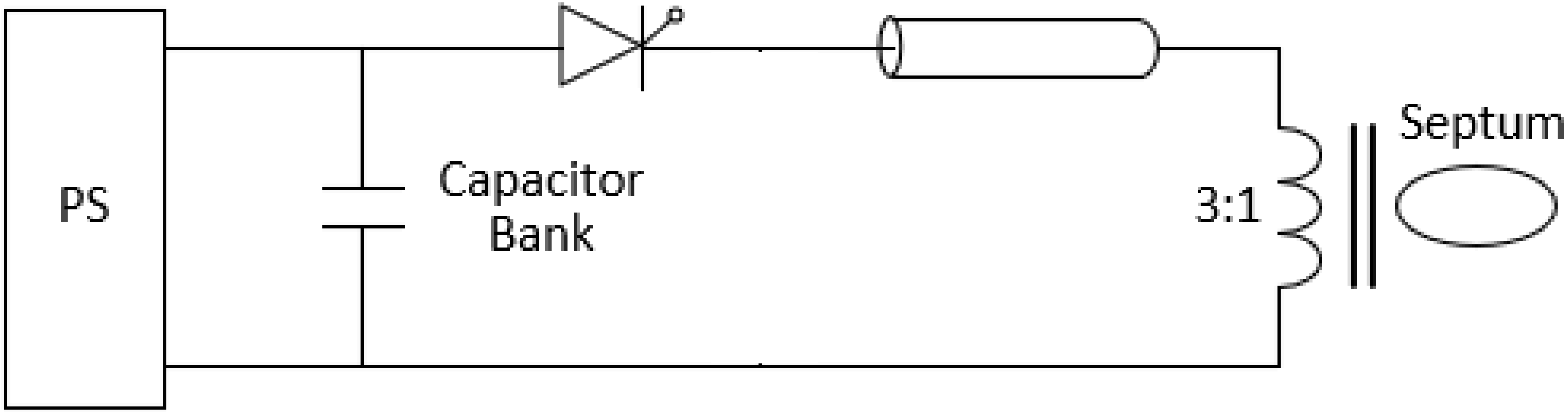
Looked at several drive pulse shapes





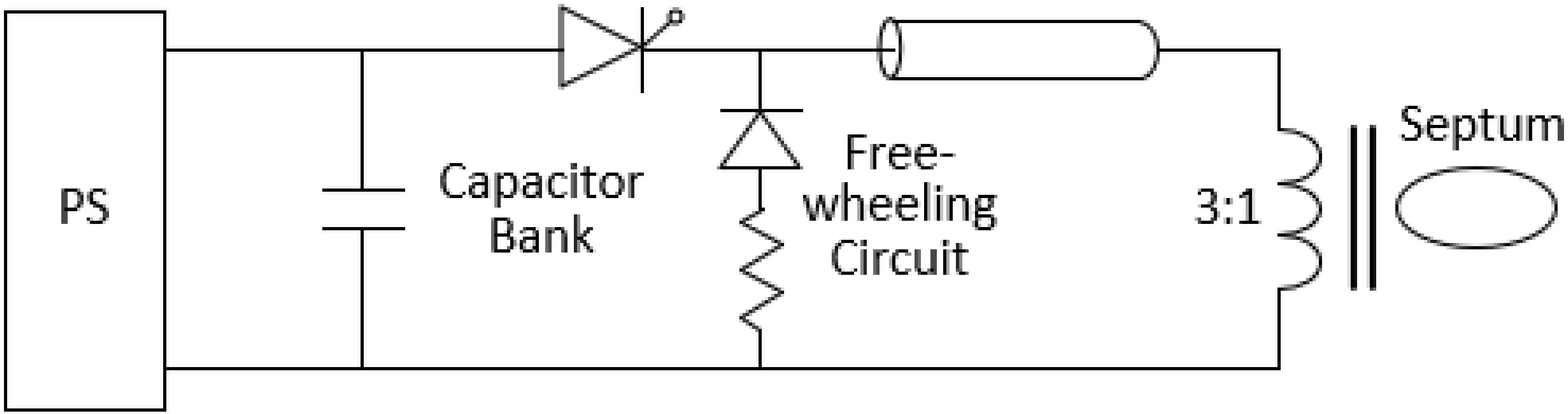
- Present APS septa use a 400μs half sinusoid drive
- This produces an undersirable rapid change in leakage field
- A tapered half sinusoid gives smoother, more correctable leakage

Power supply modification is simple



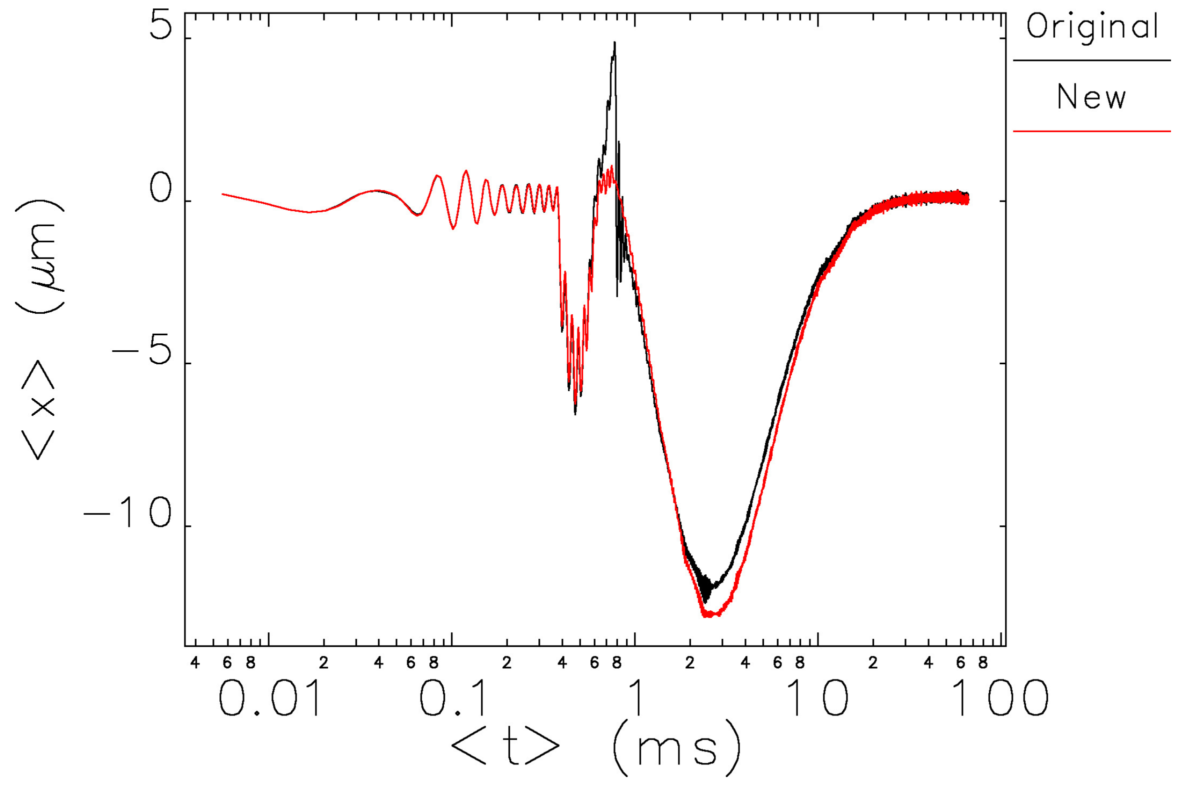
- Present PS[6] uses an SCR switch to discharge a capacitor bank through the septum
  - SCR terminates pulse abruptly as it acts like a diode

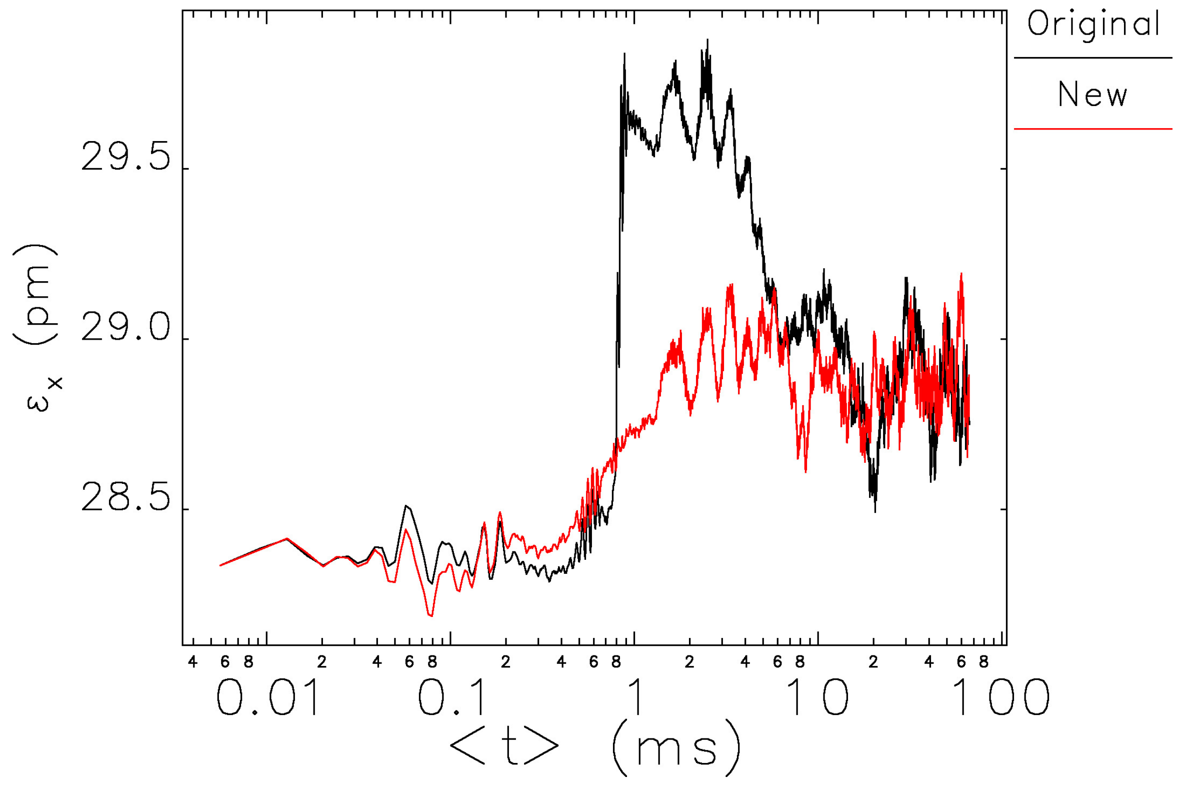
Power supply modification is simple



- Present PS uses an SCR switch to discharge a capacitor bank through the septum
  - SCR terminates pulse abruptly as it acts like a diode
- Adding a free-wheeling circuit (diode + resistor) allows gradual dissipation of stored energy, smoothly tapered current

Smooth taper is helpful, but not sufficient



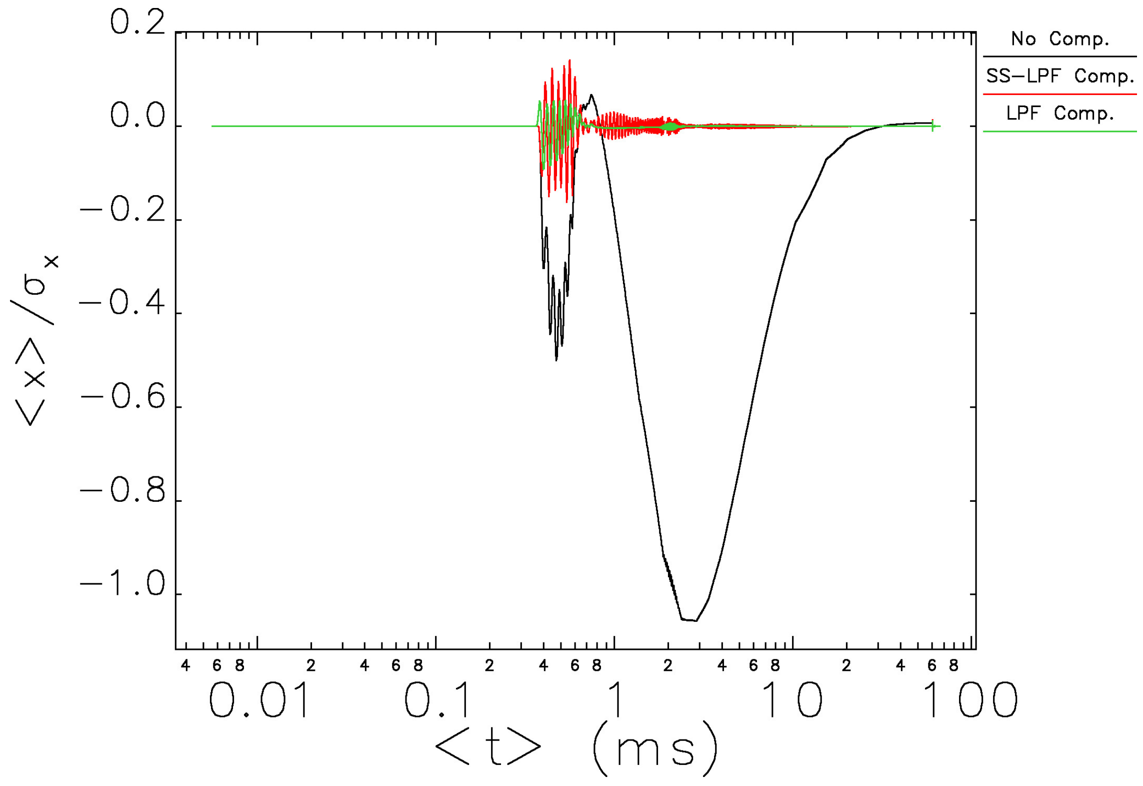


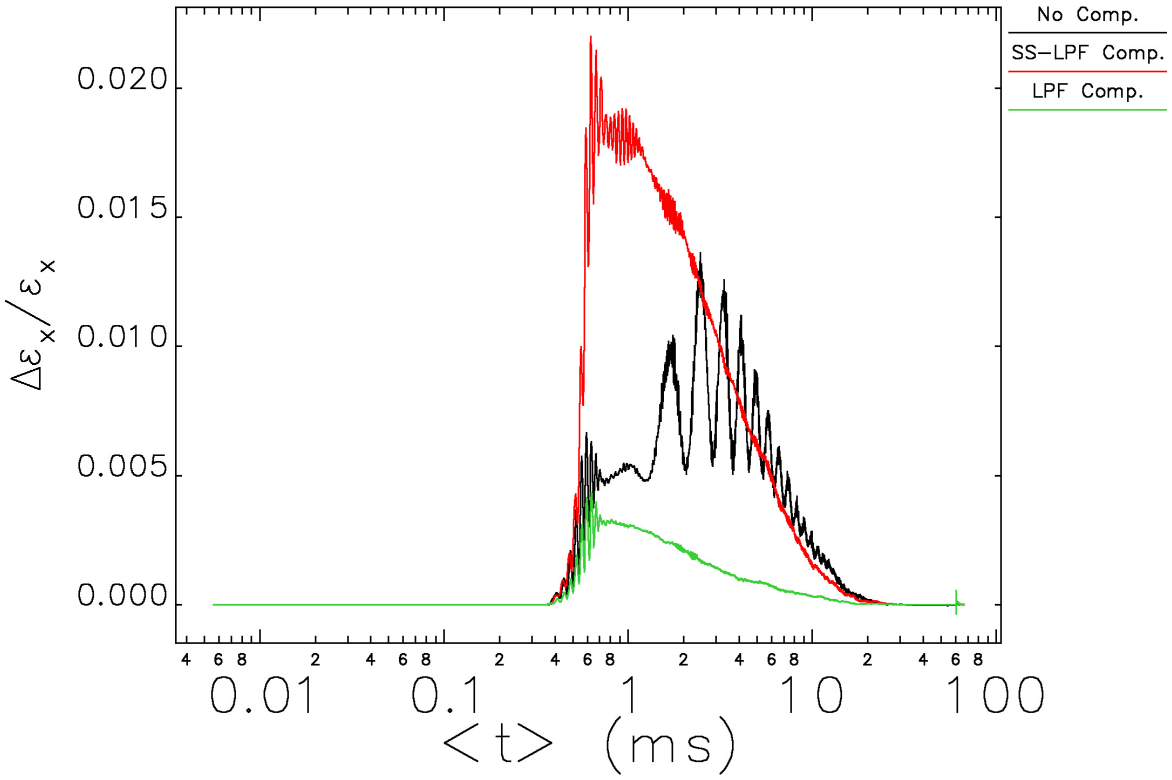
- The smooth taper eliminates emittance bump that occurs due to the leakage field spike
- Beam motion still about 100% of beam size

Explored two compensation schemes

- Can compensate leakage with fast steering correctors
- Two options
  - Use feedforward to drive two nearby correctors[7], with updates at the 22.6 kHz FOFB[8] rate
    - Produces a “stair-step” pattern
    - 10 kHz low-pass filter from magnet and vacuum chamber[9]
  - Use AFGs to drive two nearby correctors, with updates at much higher rates
    - Smooth, but still filtered by 10 kHz LPF

AFG-driven scheme much more effective

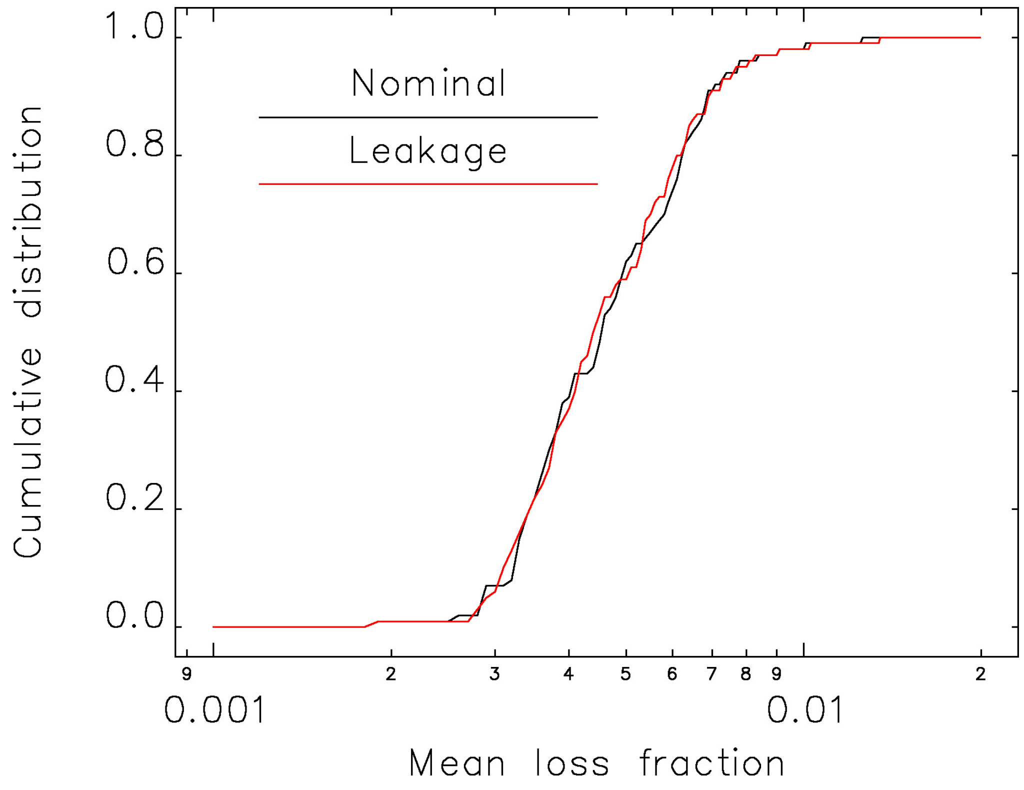




- Both schemes correct the long, slow post-pulse orbit motion
- Driving with a SS waveform makes emittance growth worse
- Not shown: variation with SS timing relative to septum pulse

No issues for non-linear dynamics

- Used time-dependent multiples to understand effect on injection efficiency
- Tracked for 54k turns, element-by-element, with 100 post-commissioning ensembles[10]
- To model small losses, used uniform distribution with gaussian weights
  - 1000 simulation particles per shot, 30 shots per ensemble,



No significant change in injection losses from leakage fields, even without compensation of dipole kicks

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Conclusion

- APS-U will use a high-strength pulsed septum
- Leakage is very low, but beam sizes are very small
- Effects of leakage field should be manageable thanks to
  - Septum design gives low leakage for dipole and multipoles
  - Power supply design that minimizes rapid changes in leakage field
  - Compensation scheme using AFGs to drive existing fast correctors

References

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Acknowledgments

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