HBAR Technologies, LLC

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Energy Jitter Correction

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H– Transport and Injection Mini-Workshop

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Main Injector Injection

- Because bucket-to-bucket transfers into the Main Injector are not envisioned, the bunch lengths coming out of the Proton Driver are not relevant. The injected longitudinal emittance is thus the energy spread times the Main Injector revolution period.
- In my opinion, the maximum longitudinal emittance that one can expect to accelerate through Main Injector transition with anything approaching 0.1% efficiency is 0.5 eV-sec.
- A system is needed to minimize the energy spread in the Main Injector at injection.

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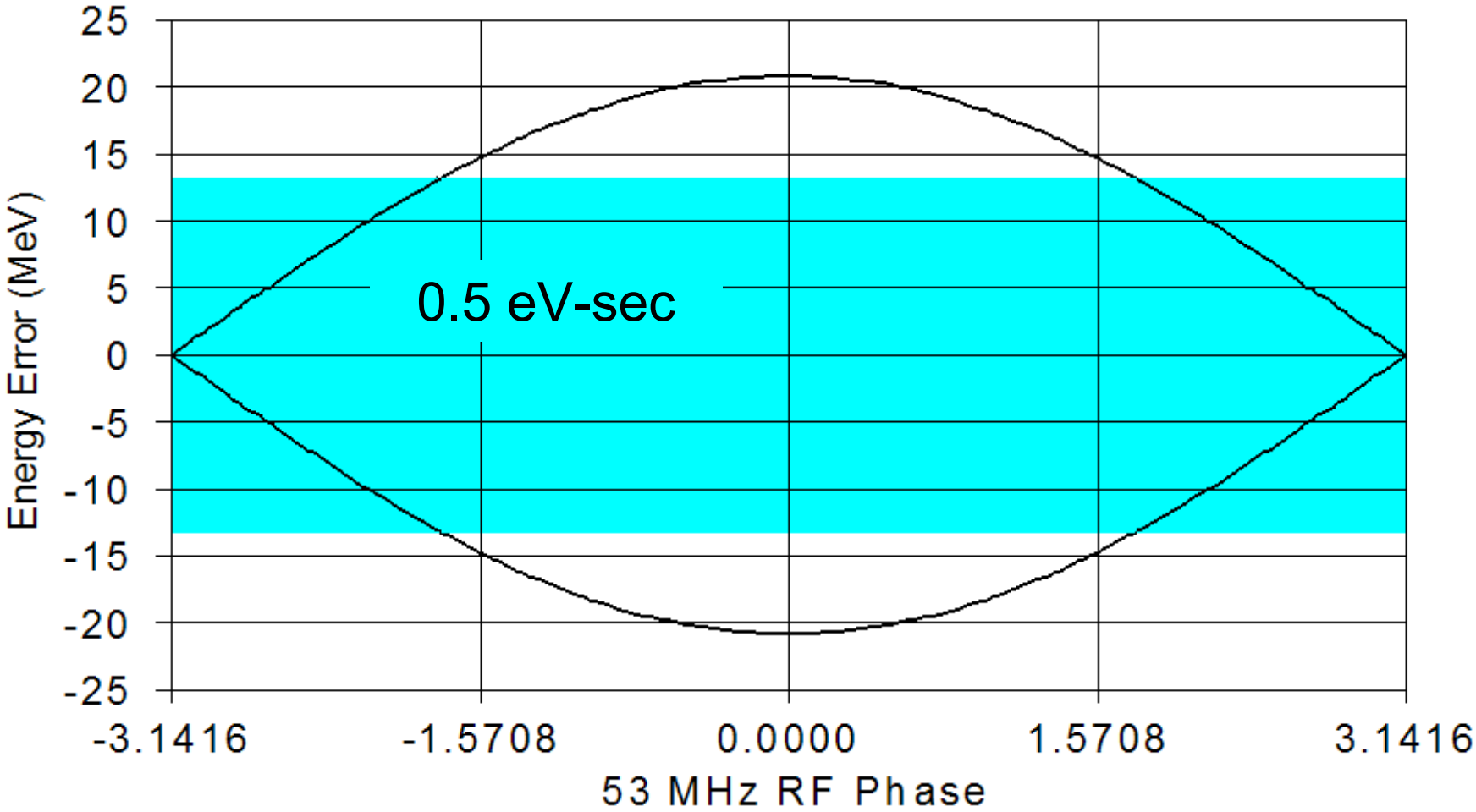
Main Injector Injection Bucket



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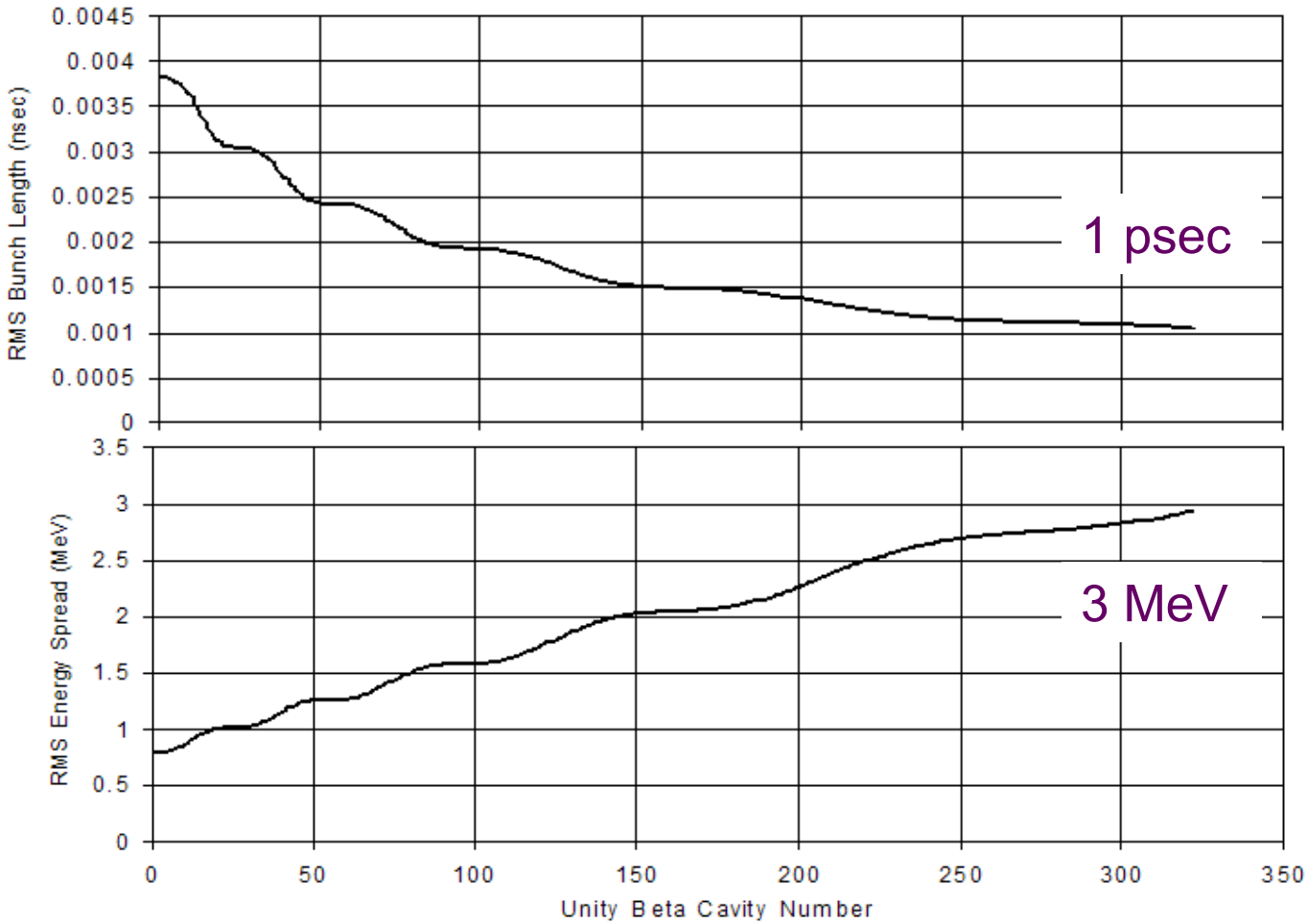
Propagating Bunch Emittance

- A longitudinal emittance of $3x10^{-6}$ πeV-s was matched to the Proton Driver unity beta section (1.1 GeV to 8 GeV) and propagated to the end of an error-free linac



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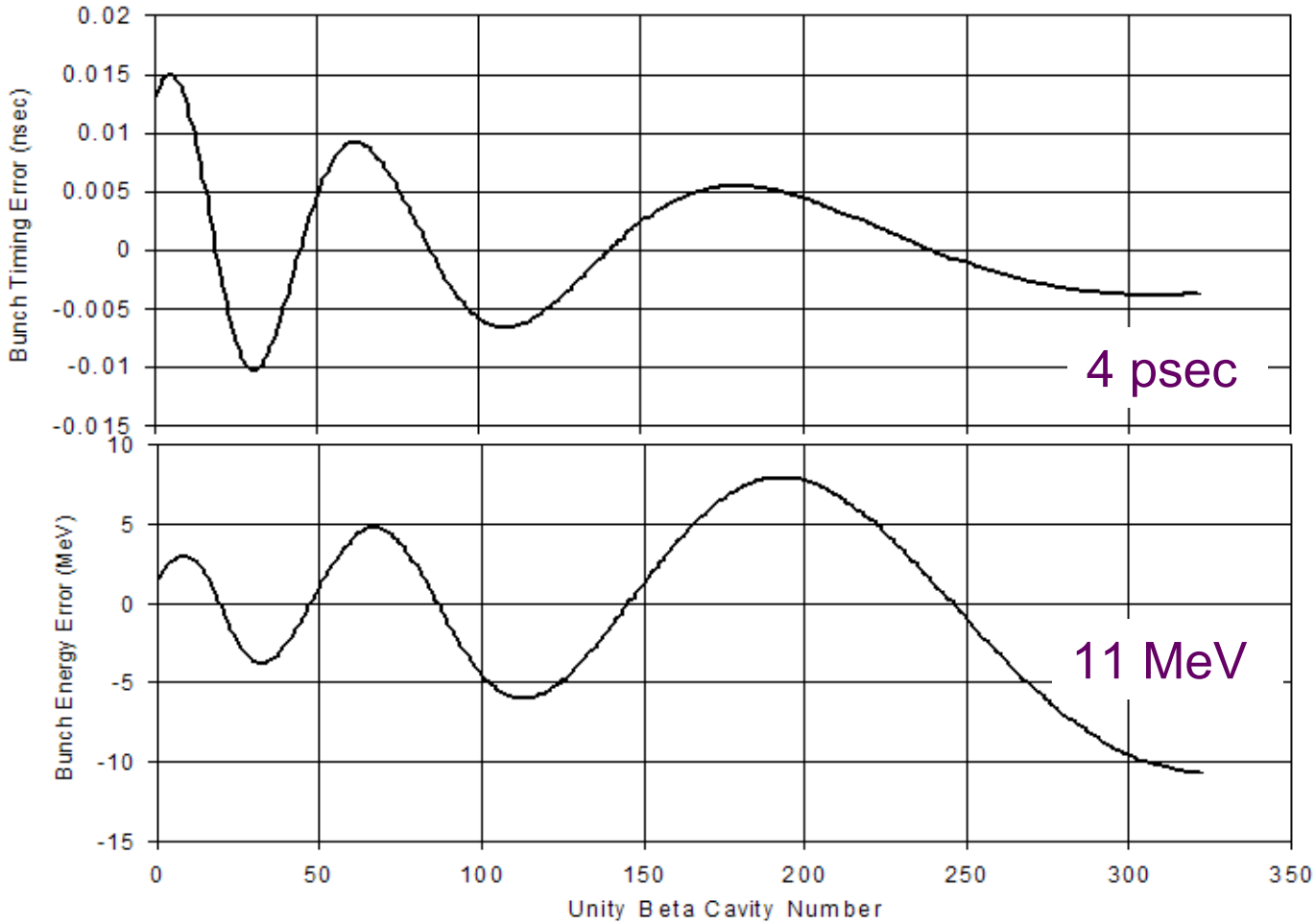
Propagating SNS Errors

- May 2004 SNS jitter errors of ±1.5 MeV & ±13 psec were propagated down an error-free Proton Driver unity beta section to generate max. phase and energy errors



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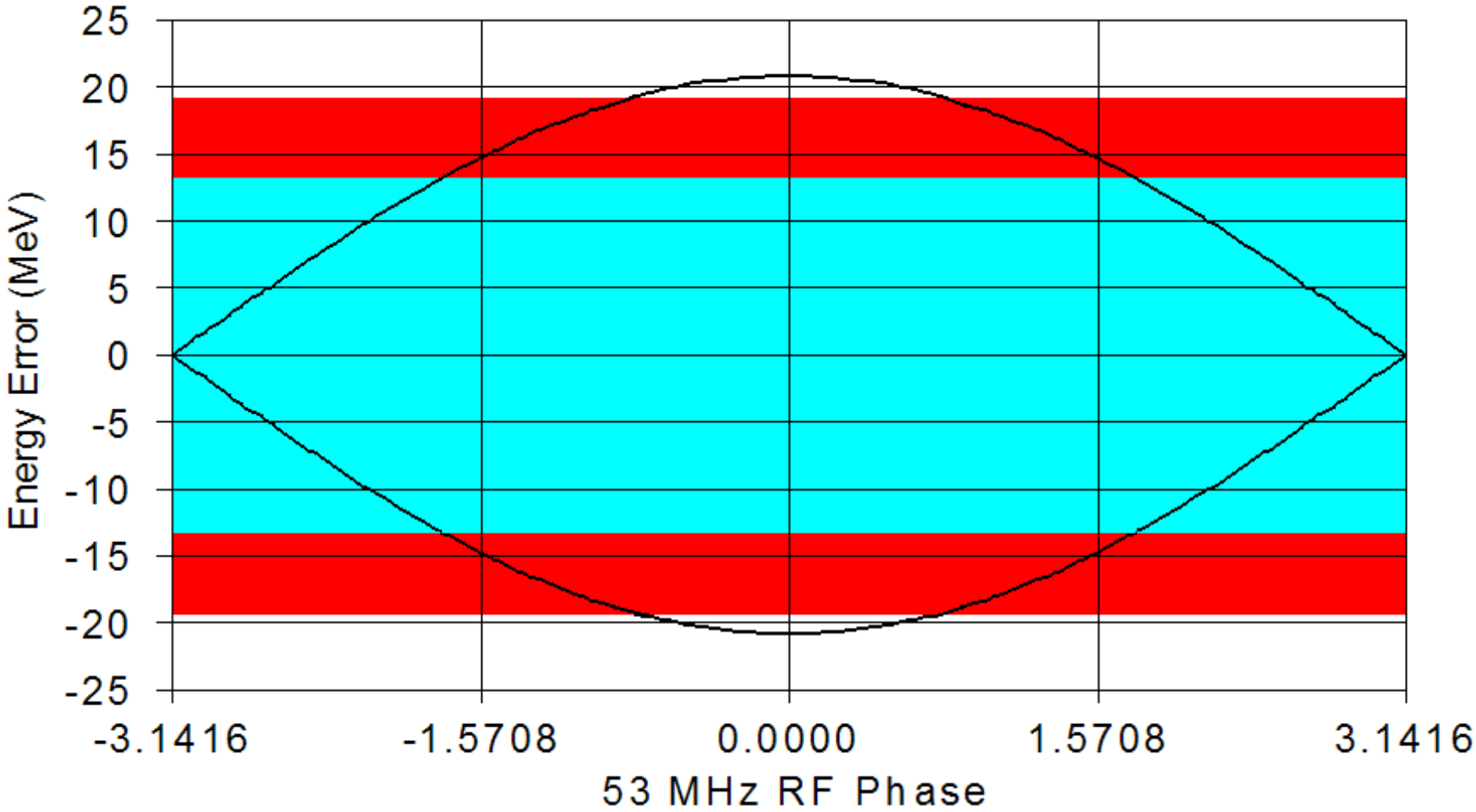
Uncorrected Energy Width



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Possible Jitter Correction

1) Avoid or reduce the jitter at the source and use superconducting spoke cavities for cleaner acceleration (lower bandwidth, smaller microphonic effects, smaller dynamic Lorentz detuning)
2) Use a vector-sum approach to feed back on the measured beam energy and phase errors to negate the energy jitter at the end of the Proton Driver.
3) Employ a debuncher cavity just before injection into the Main Injector that is operated open-loop.
4) Increase the waveguide coupling in the debuncher cavities to decrease the Q and employ feedback.
5) All of the above.

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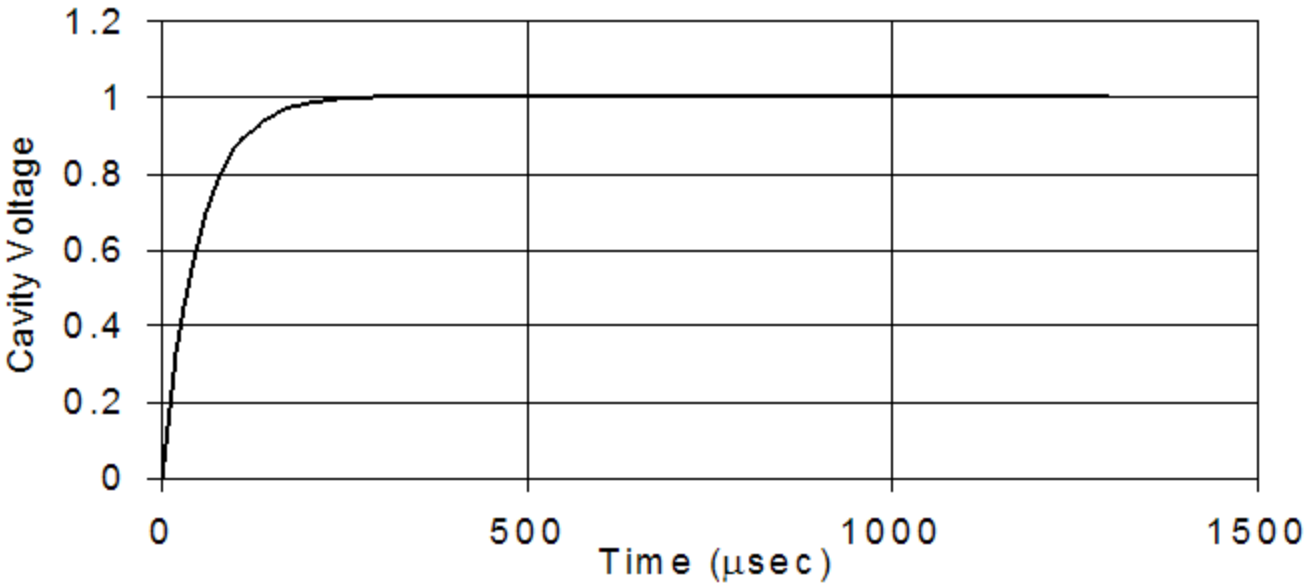
Vector-Sum Approach



In each cavity up the Proton Driver, a 1° phase change requires 0.88 μs, allowing correction of bunch-to-bunch jitter up through 1 MHz.

- Assuming a 50 μs filling time as shown here, a 1° phase change requires a quadrature vector of 0.0175x the main drive vector. Feedback the measured bunch energy and phase errors at the end of the Proton Driver for corrections.

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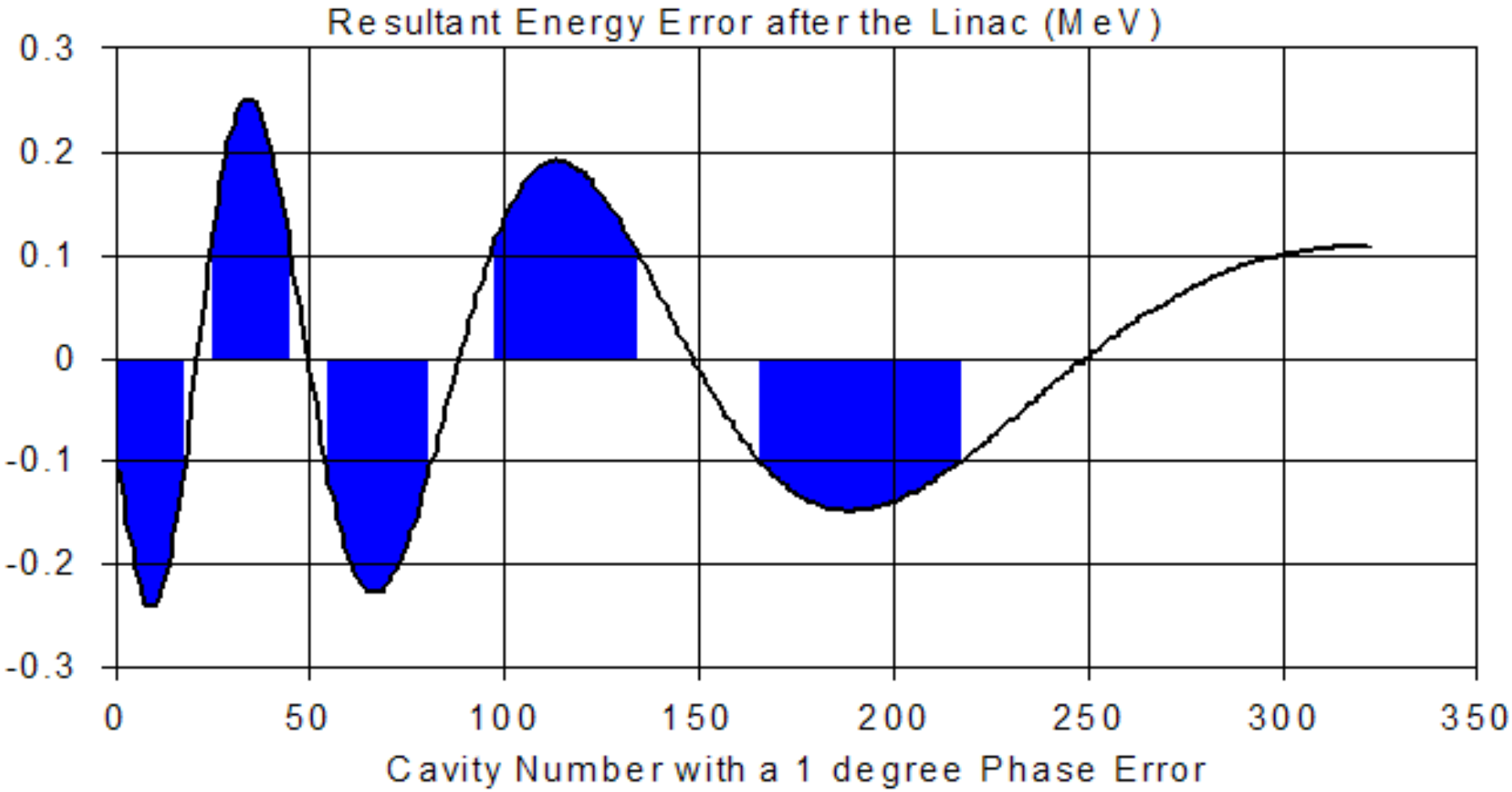
Simulation of Vector-Sum



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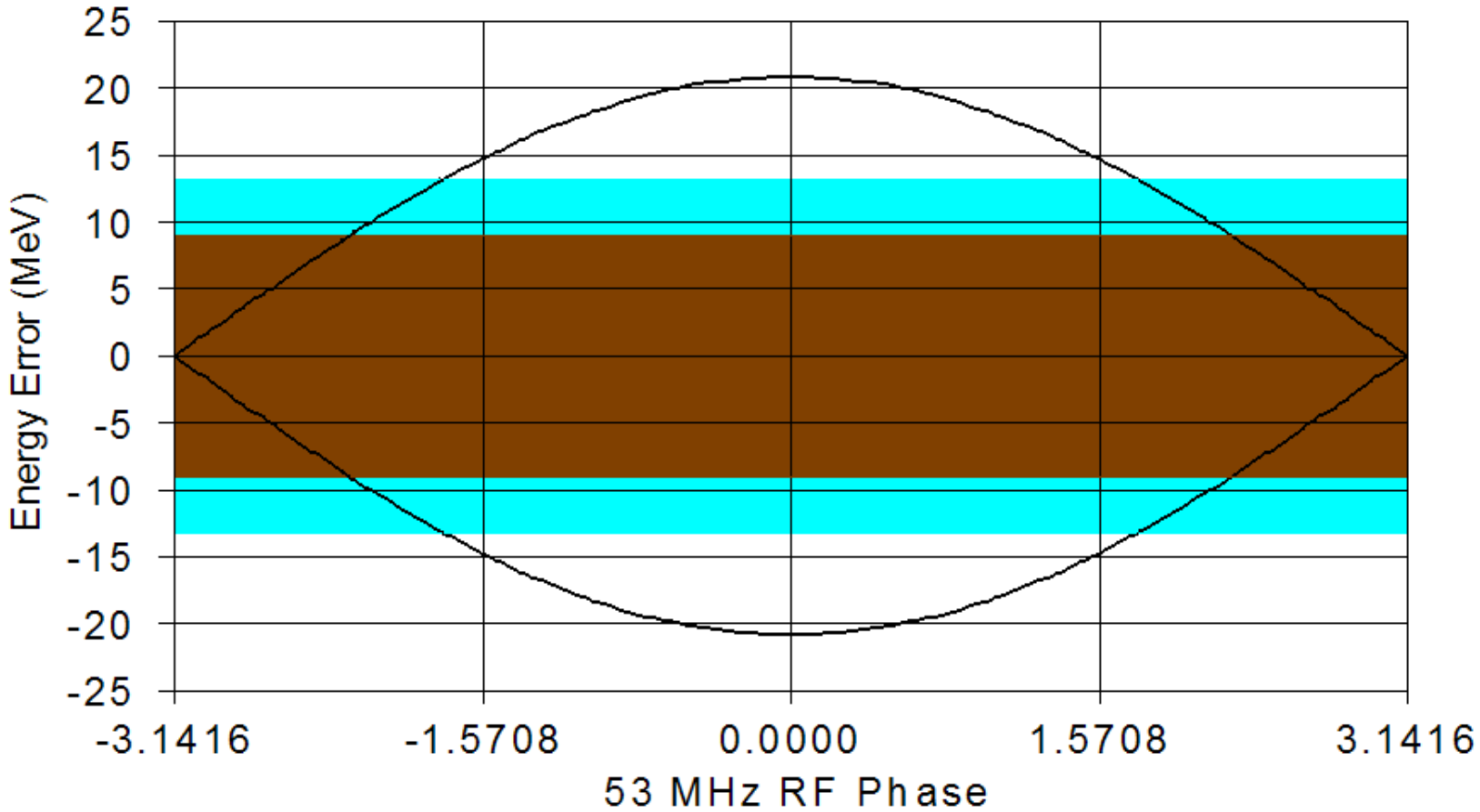
Vector-Sum Peformance



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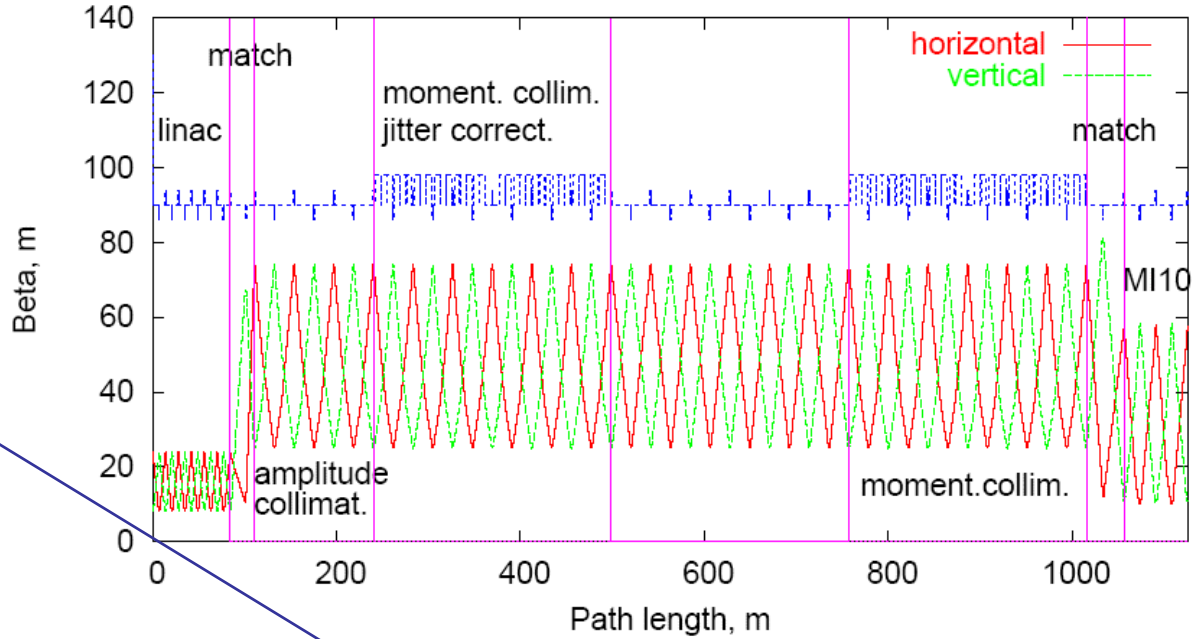
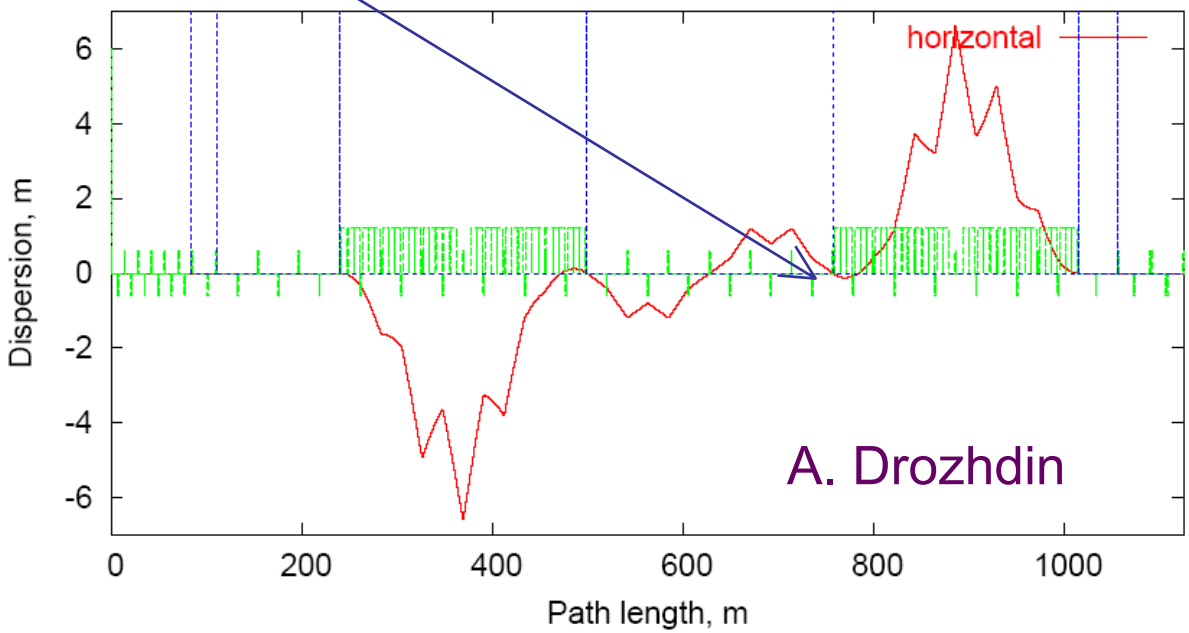
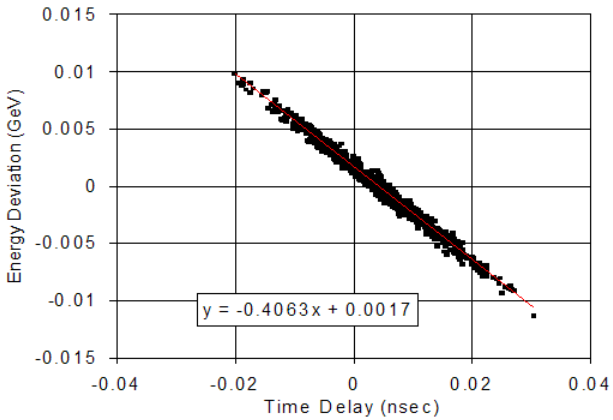
Passive Debuncher

Assume a 50 MV debuncher section 650 m after the Proton Driver.







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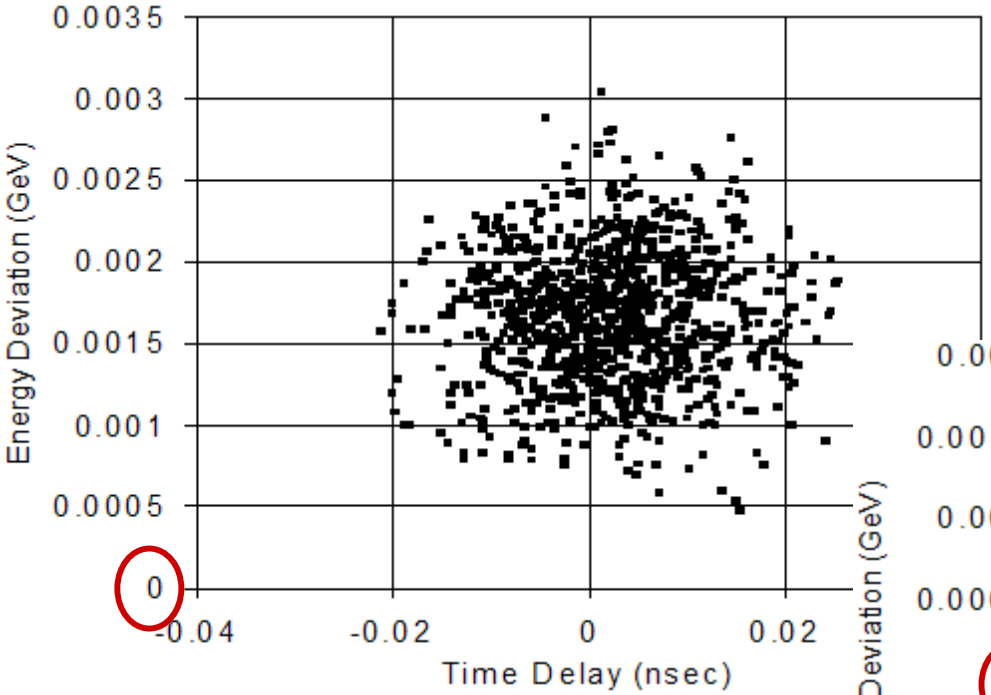
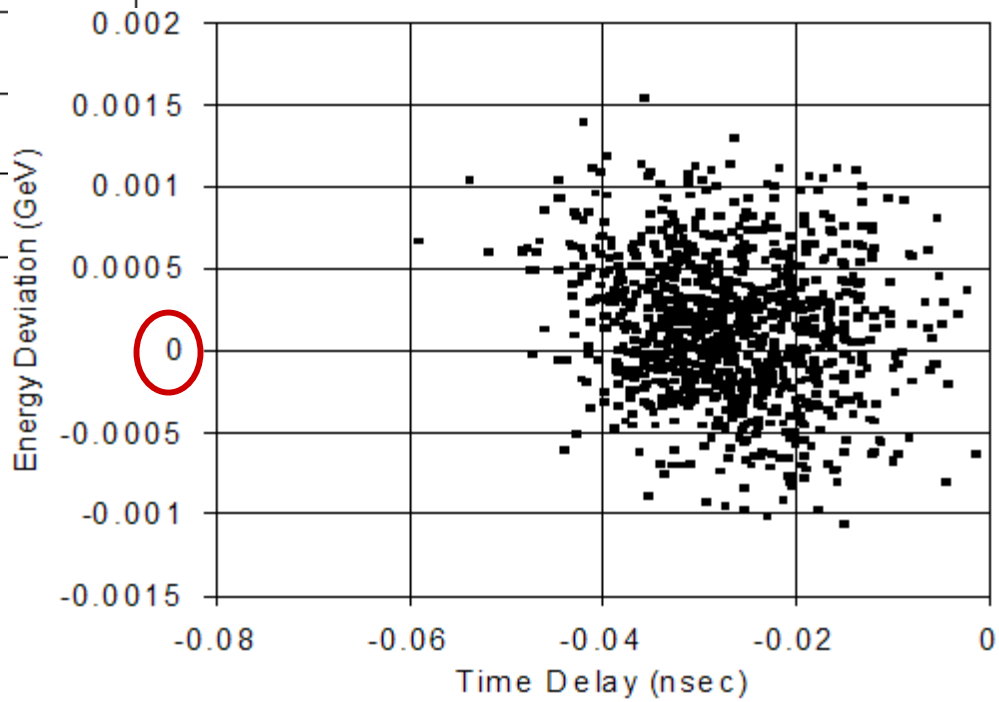
Passive Debuncher Output



Result of a 4 psec phase jitter out of the Proton Driver, after the Debuncher

Result of a 11 MeV energy jitter out of the Proton Driver, after the Debuncher



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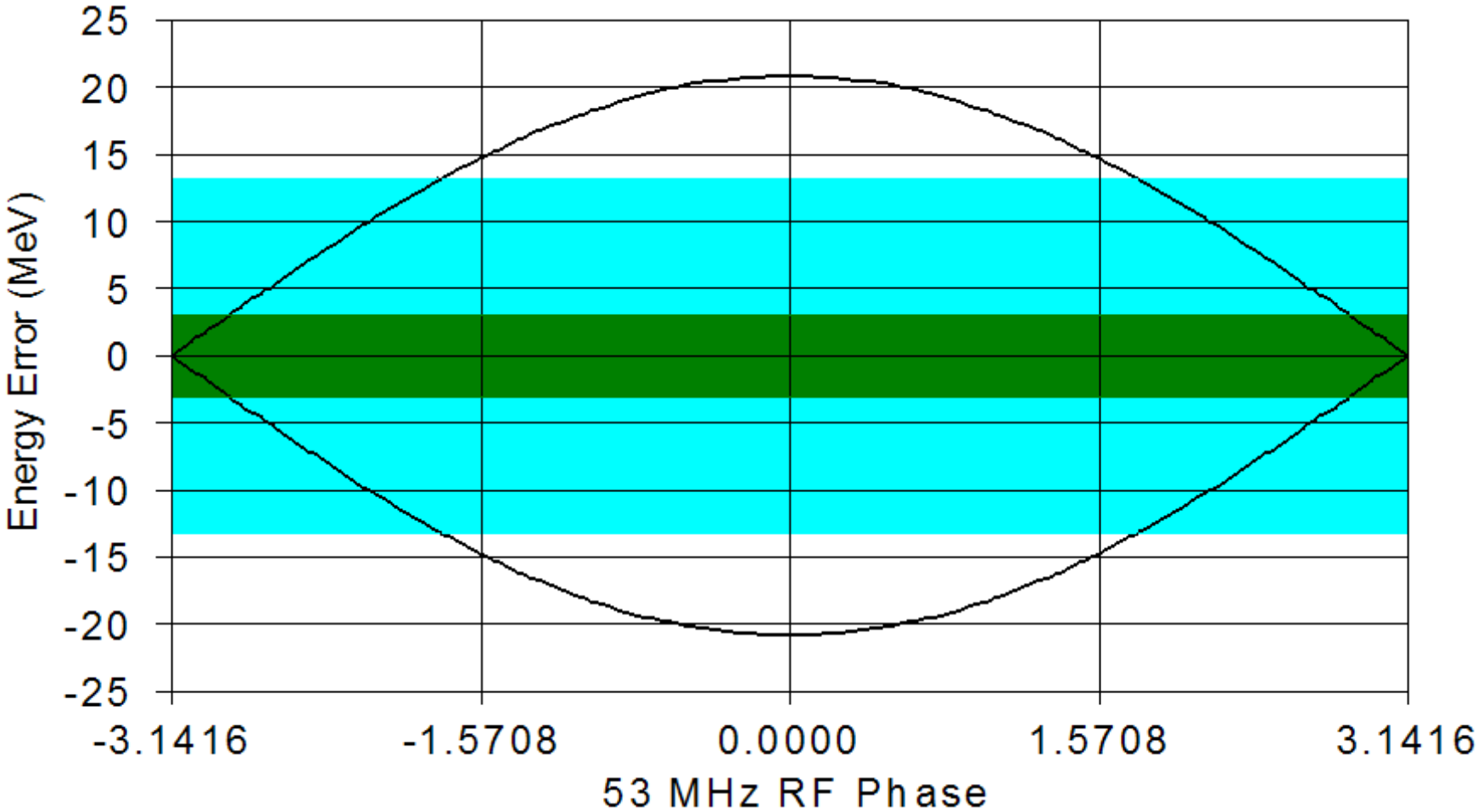
Debuncher Only Performance



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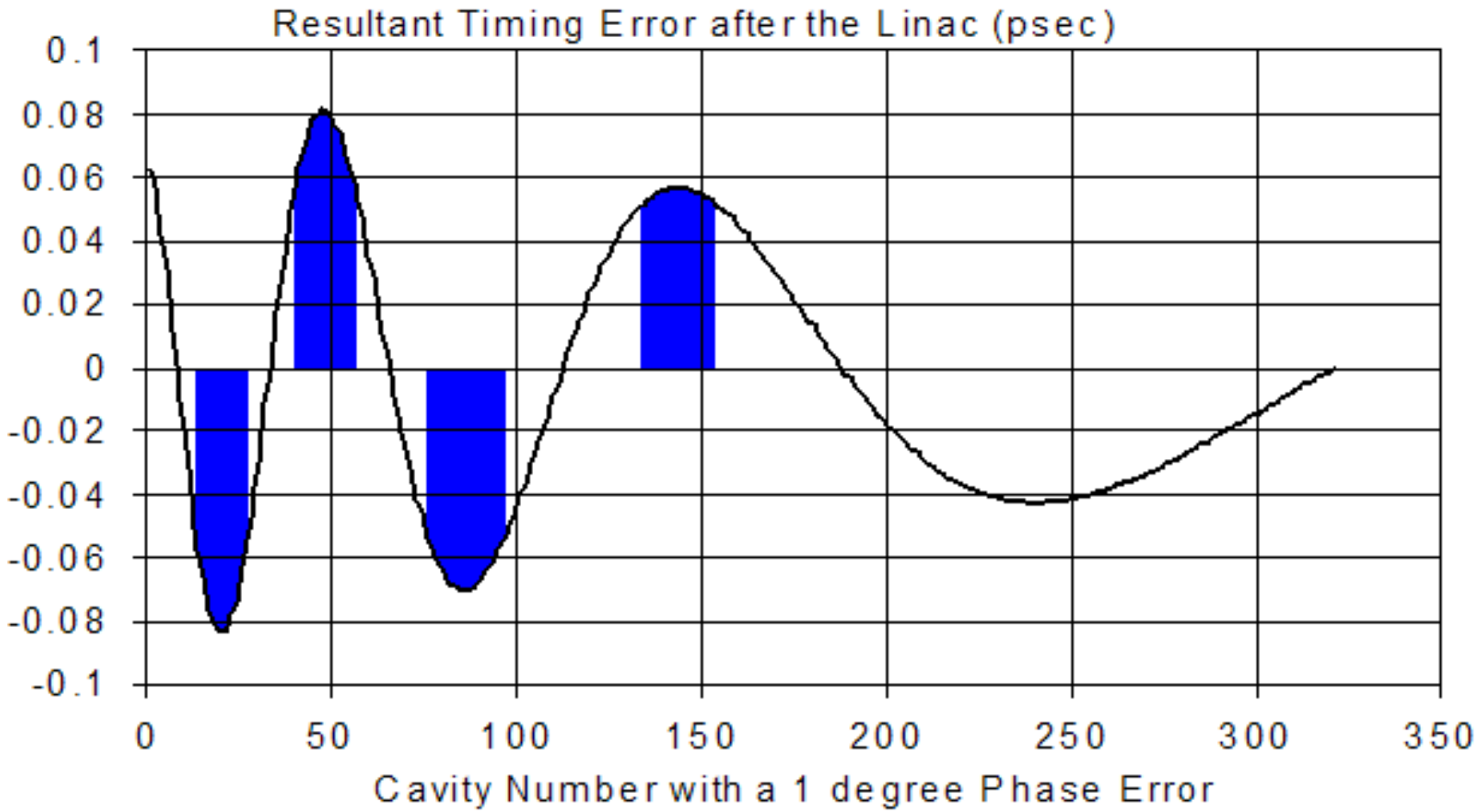
Vector-Sum Phase Feedback



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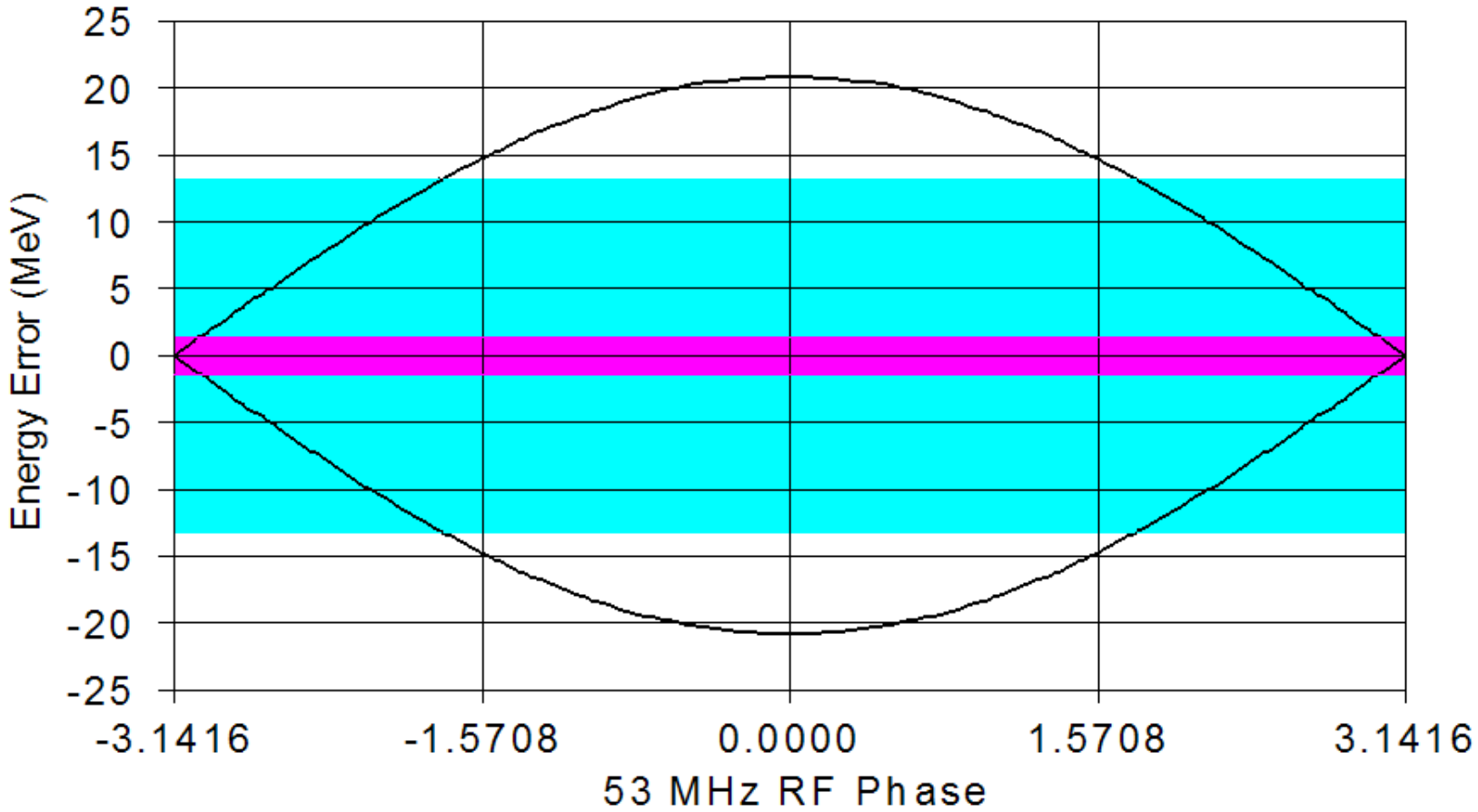
Phase Jitter Fix + Debuncher



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Jitter After 1 GeV

- The frequency content of any jitter generated in the unity beta portion (1.1 GeV to 8 GeV) portion of the Proton Driver is limited by the bandwidth of the cavities and the (audio) resonant frequencies of the cavity structures.
- Any correction system is also limited by the same bandwidth of the cavities, so the local cavity fanback loops can eliminate these errors.
- In addition, a vector-sum system can also eliminate this portion of the phase and energy jitter at the end of the Proton Driver.
- Page 33 of TM-2169 contains a calculation of energy width assuming microphonic amplitudes 3x that measured by SNS. Though wild optimism is bad in accelerator design, overtly excessive pessimism is equally fatal. Scaling these results down to reasonable input parameters, the previous results are not significantly modified.

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Conclusions

- Many thanks for useful discussions with Pierre Bauer, Bill Foster, Jim MacLachlan, Petr Ostroumov, Milorad Popovic, Gennady Romanov, and many others…
- Uncorrected energy jitter at the output of the Proton Driver, derived from SNS jitter assumptions at 1 GeV and propagated to the end of the machine, shows the need for some type of correction system.
- Vector-sum compensation of the energy jitter out of the Proton Driver reduces the energy distribution width sufficiently by itself to enable clean Main Injector injection and acceleration.
- The use of a passive debuncher cavity is a superior mechanism for reducing the injected energy width in the Main Injector.
- Applying phase feedback to the debuncher cavity, or applying vector-sum phase feedback to correct the beam phase at the debuncher cavity, produces the smallest energy spread.