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Project X Workshop
MI Transverse Dampers

• November 12th-13th, 2007 •

The "current" system

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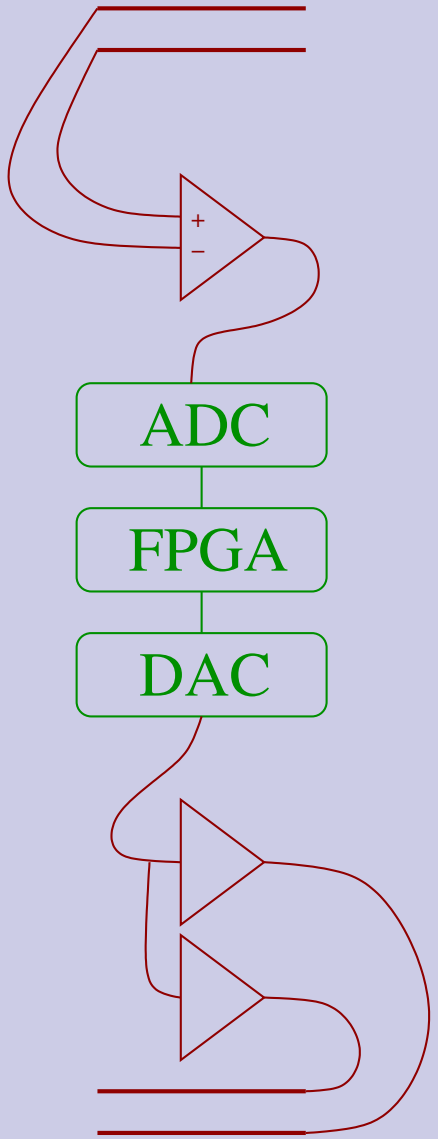
- 30cm stripline pickups
- 1m stripline kickers (50 Ω)
- One 500W broadband amplifier (10kHZ → 100 MHz) per plate
- Maximum kick: 100μm amplitude per turn



The "current" system

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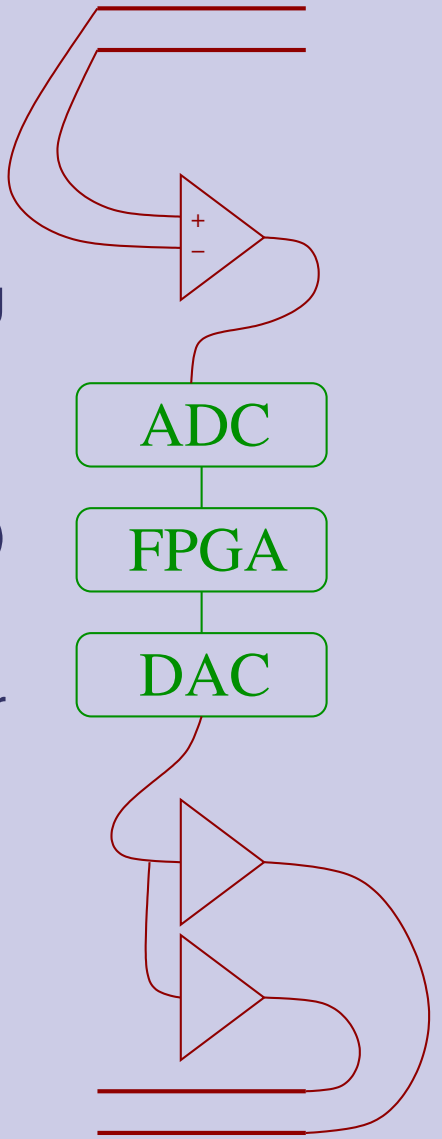
- VME card: Bunch by Bunch digital damper
- 212 MHz 12-bit ADCs
- Stratix II FPGA (decodes MDAT, TCLK, BSYNC. Flexible state-based damping logic.)
- 3-turn FIR filter to extract transverse oscillation for damping
- 14-bit DACs clocked at 636 MHz
- System will be installed in Main Injector over next several weeks (replacing functionally similar but less flexible board)
- Board supports 1GB RAM for diagnostics etc.
- An identical system will be installed in the Recycler for NOνA



Old system in action

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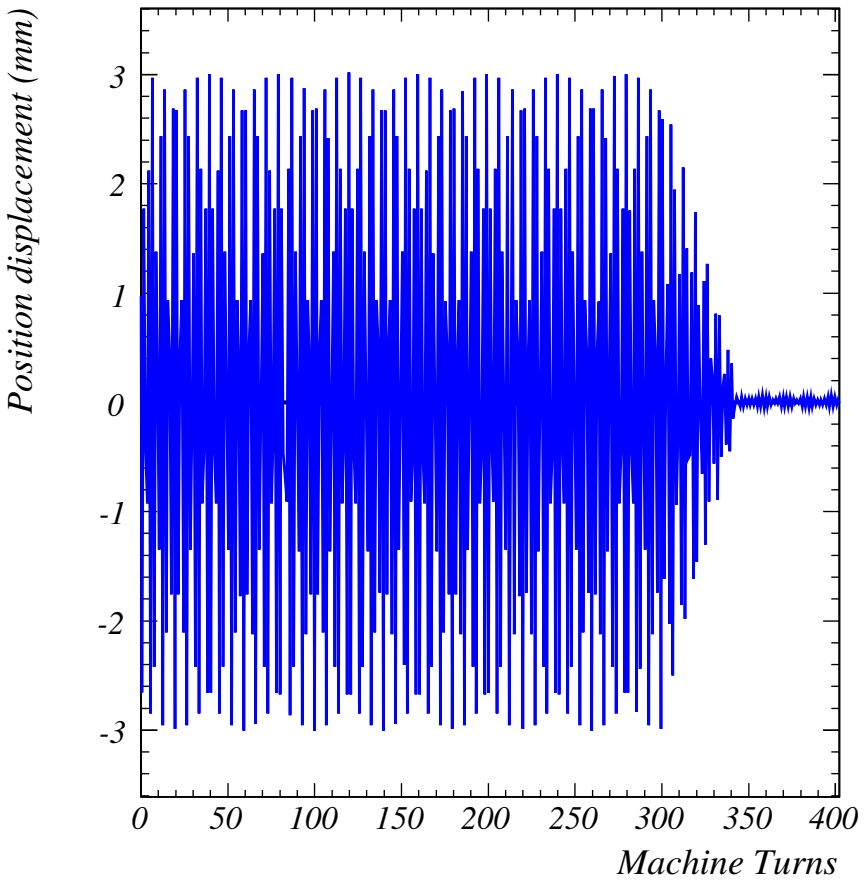

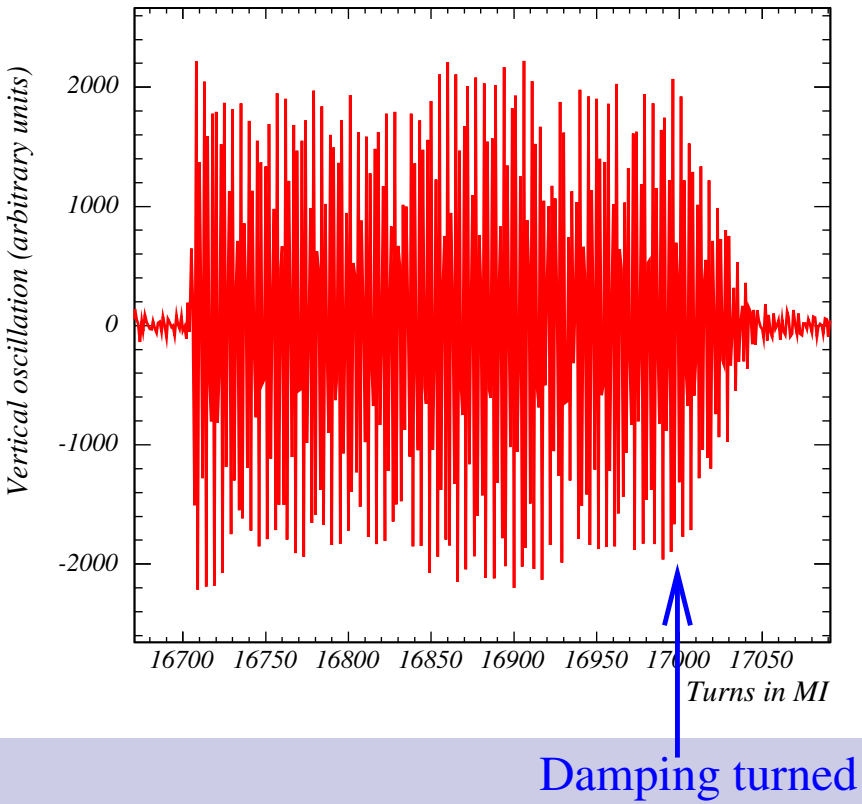

- Ideal simulation (left, blue) and data (red, right) show fairly good agreement
- (Full scale on red plot is about 3mm)
- Full kick gives about 100μm amplitude oscillation

Injection or Instability?

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Instability Damper

- Damping rate must exceed growth rate of instability
- Don't need an enormous amount of power if you have a low enough noise floor
- All you need is gain

Injection Damper

- Begin with some superposition of transverse modes excited
- Need more power to prevent instability now
- Need power to damp oscillation quickly before emittance dilution

Some measurements

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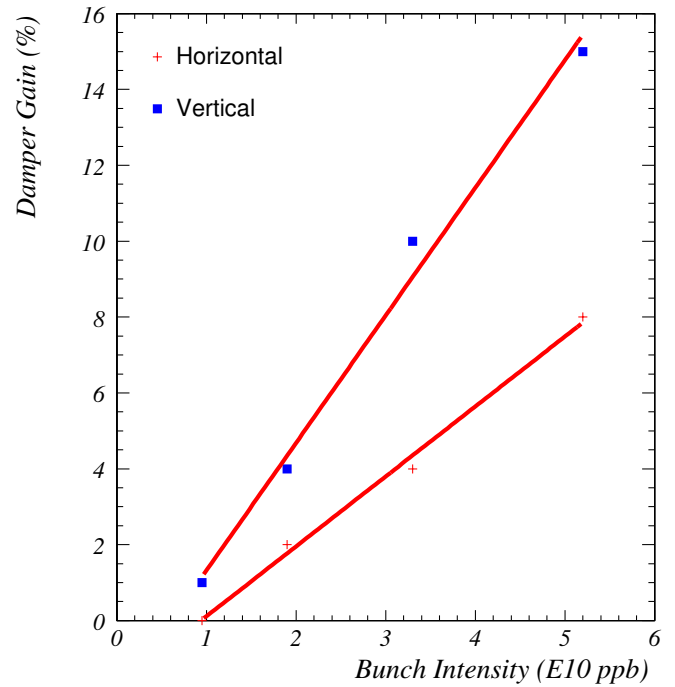
- Growth rate of lowest unstable transverse mode:
- Measured growth rate (P. Adamson, X. Huang,...)
  - $\Rightarrow 338 \pm 17 s^{-1}/E10$ protons/bunch (Vertical, 480 bunches, chromaticity close to zero)
  - $\Rightarrow 286 \pm 16 s^{-1}/E10$ protons/bunch (Horizontal, 480 bunches, chromaticity close to zero)
- Calculation (Martens & Ng)
  - $\Rightarrow 476 s^{-1}/E10$ protons/bunch



- Turn down gain of old damper system until beam falls out of machine (Zwaska)
- Gives required gain for instability damping with old system
- New system has lower noise by a factor of several

Some numbers

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- Current operation of the Main Injector: 6×10^{10} protons per bunch
- (11×10^{10} ppb with slip-stacking)
- NoVA upgrades will increase the repetition rate, but not increase these numbers appreciably
- Project X: 1.4×10^{14} protons in 548 bunches $\rightarrow 31 \times 10^{10}$ ppb

- Proposal is to run MI with chromaticity of -20 for Project X. This gives a form factor of about 0.2, and so reduces the growth rates by a factor of 5.
- Growth rate for lowest vertical mode should then be about $68 \mathrm{s}^{-1}/\mathrm{E10\ protons/bunch}$
- $2100 s^{-1}$, which is about 50 turns^{-1}
- 50 turns damping rate is achievable with current system, unmodified
- Zwaska plot says critical value for full gain is about 30×10^{10} ppb, but that was
  - $\Rightarrow$ With "short" bunch length. Slip-stack or Project X beam should be more stable by a factor of maybe 2.
  - $\Rightarrow$ With chromaticity close to zero. $\xi = -20$ should buy us a factor of 5 from the form factor.

But I want 10 turns

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- ...because I want to kill injection errors before I get emittance dilution
- ...because I want the damper to kill an instability driven by electron cloud
- ...because the numbers in this talk are wrong
- ...because I might want to run with a chromaticity closer to zero if I can

So I want more power. What can I do?

- $1M will buy you 3.5 kW broadband amps to replace the 500W ones currently in use. This is the trivial solution - it takes no work, but just costs money. You'd want to do the same for Recycler, of course...
- Or you could decide that for $2M, you should try to be a bit smarter

Something smarter

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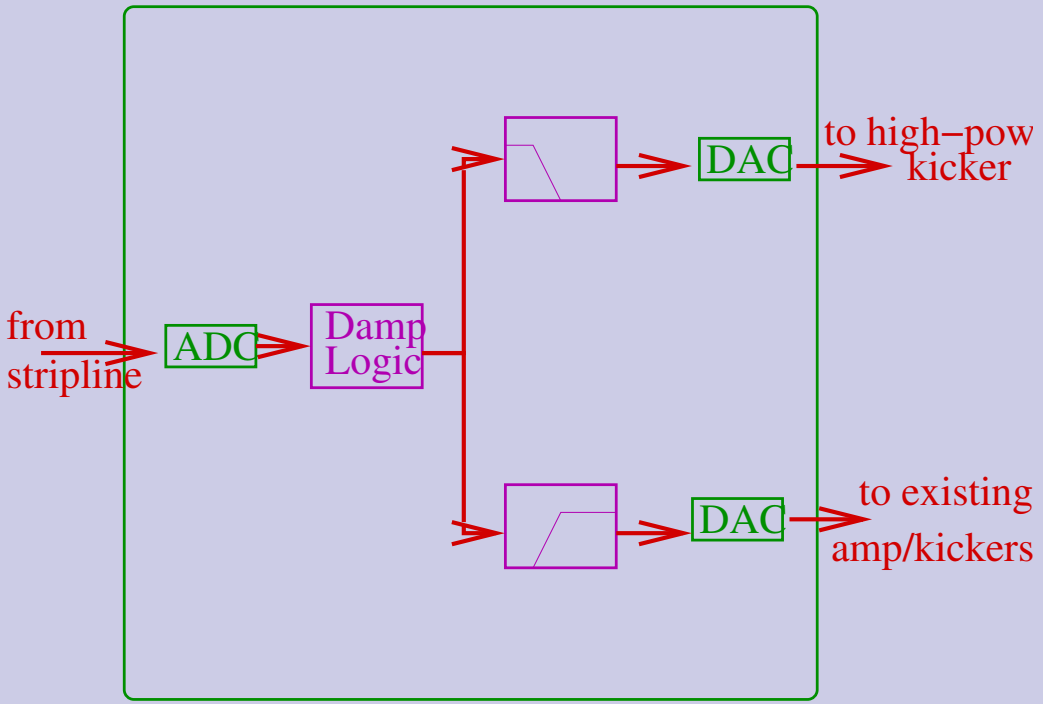

- Only need large power in the low-frequency modes
- Could sit a power tube on a high-impedance stripline and get maybe 2kV per plate up to 1MHz for a few $10Ks.
- This would give a kick stronger than the current system by a factor of about 7.
- Nice clean low- and high-pass filters are easy in the FPGA
- Could even play some feed-forward games with injection errors (assuming errors are fairly repeatable—kicker slope, ripple)

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