MICE: Muon-RF Timing

Alex Dick and Kevin Ronald

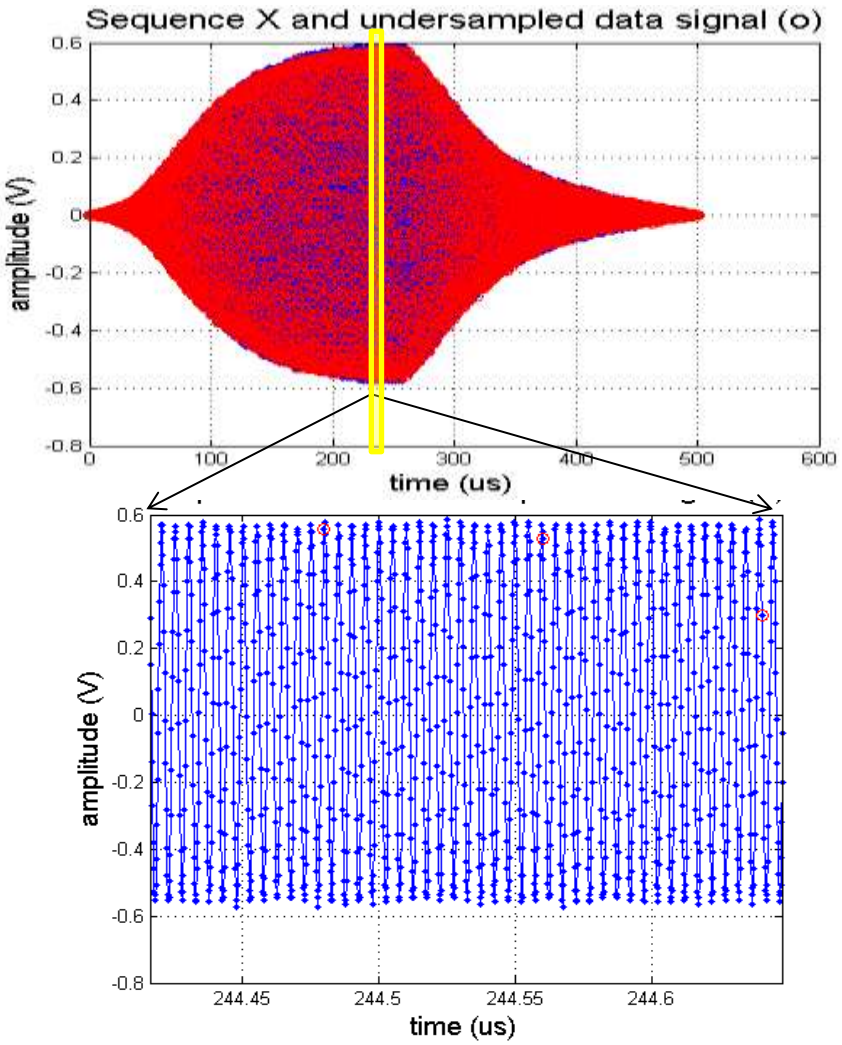
Muon Transit Phase Detection

- Need to be able to select particles for analysis by their RF transit phase
  - Allows the 'bundling' of particles for coherent analysis
  - i.e. As if we are considering the interactions of a real particle 'bunch'

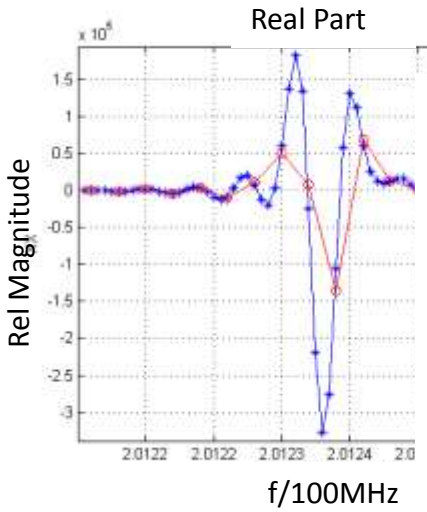
- Cavity transit time inferred by the ToF transit time and the tracker measurement of momentum
  - Combining ToF resolution and Momentum projection resolution ~ +/- 51.5ps
  - Desire to know RF phase to better than 0.3 of this ~ 17ps

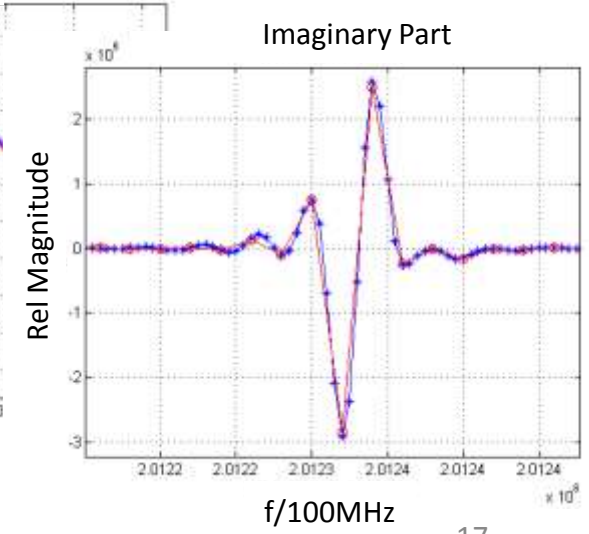
- Two Approaches
  - Digitisation (subsampled) of the RF waveform on the pickup probes
  - Direct recording of the wave inside the cavity
  - TDC recording of the RF waveform
  - Records zero crossings of a reference oscillator/Cavity waveform - provides RF phase reference for TDC particle events

Muon Transit Phase Detection



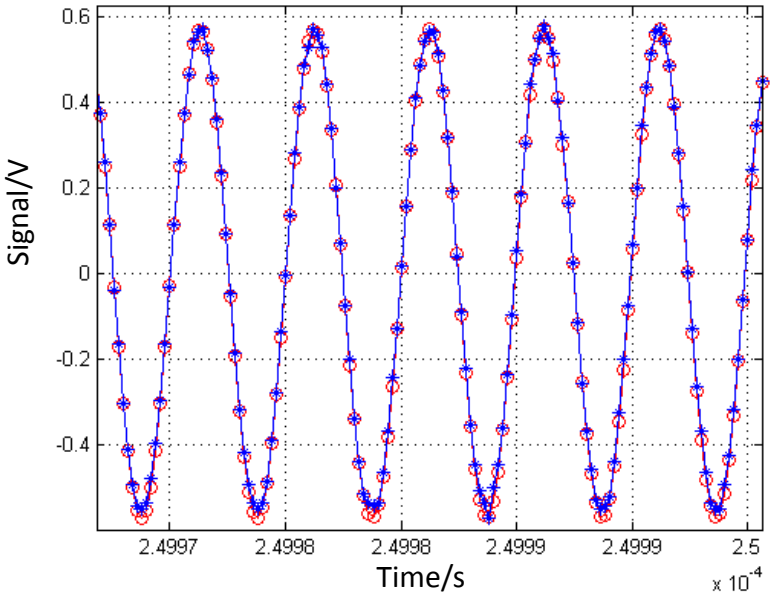
- Time domain: signal (blue) from FNAL cavity tests - 500μs window sampled at 5G.Sa/sec
- Subsample (red) at 12.5M.Sa/sec, reduce data by x400, and 48x < Nyquist @ 200MHz
- Note time domain signal 'windowed': New data from MTA will remove this process
- Freq. domain: Red fft of entire recorded data, Blue enhanced dft of subsampled data

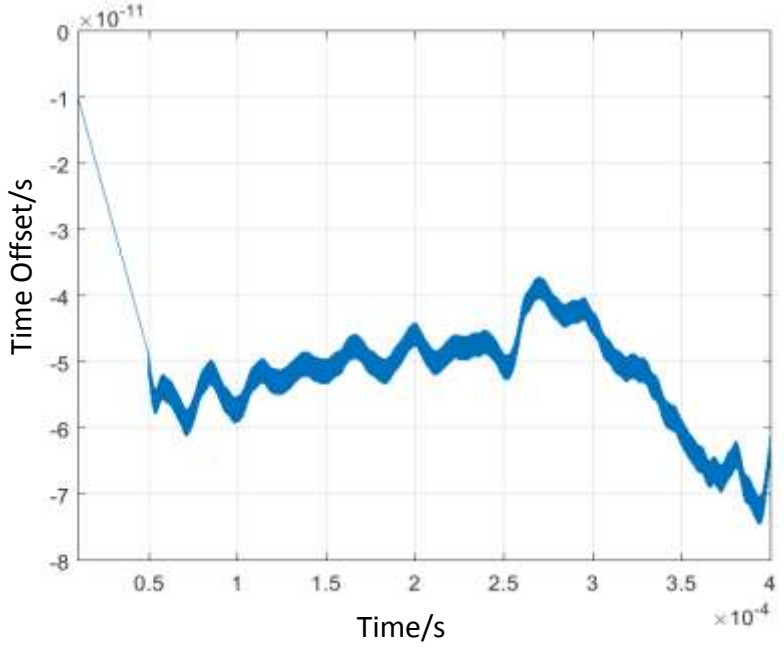




Muon Transit Phase Detection

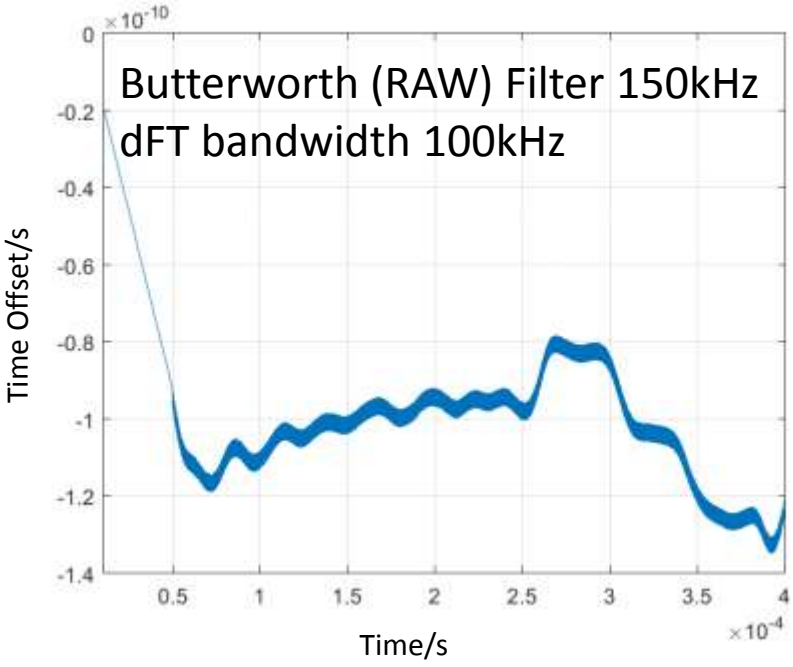
- Freq. domain reconstructions: high fidelity to raw signal over entire pulse duration (no spark)
- Blue is original data through Butterworth filter, Red is reconstructed subsample data
- Note dft here is effectively a (hard edged) 100kHz filter
- 10ps precision achieved on pulses from MTA tests

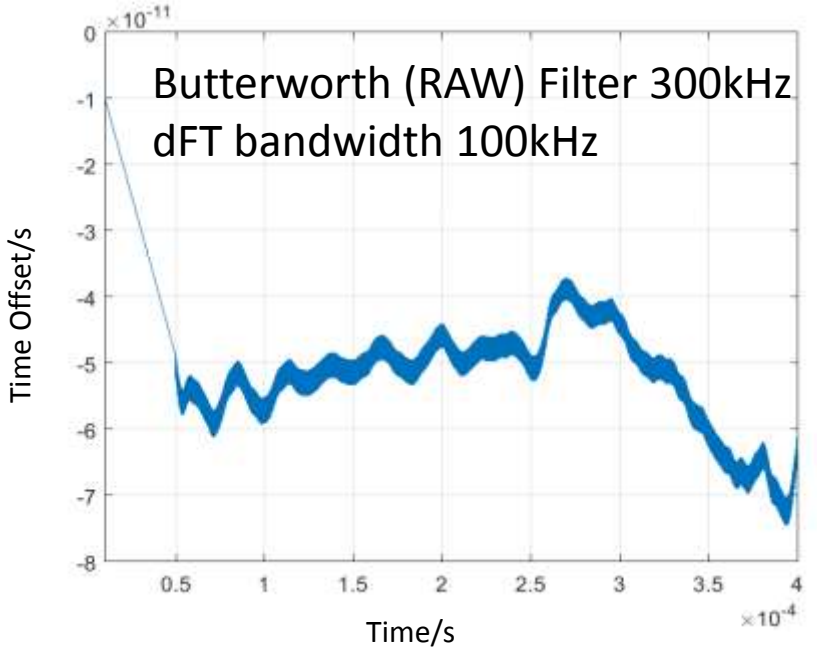




Muon Transit Phase Detection

- The effects of the filter bandwidths were considered:
  - Both dft used for the FD reconstruction and
  - Butterworth applied to the raw data
- Width of Butterworth filter: Minor impact on noise at 5ps level, significant impact on systematic offets
- Width of dFT- affected resolution of fine scale variation in signal- no significant impact on systematic offsets





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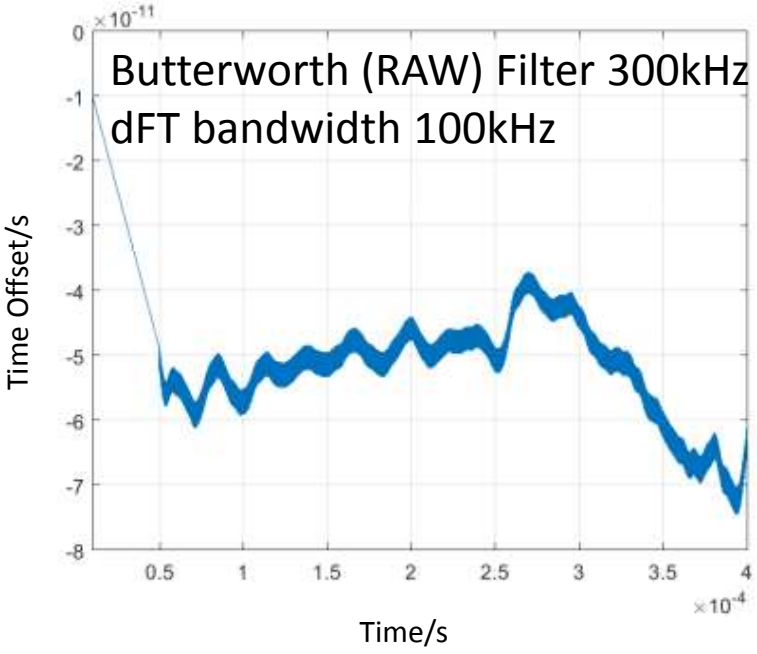
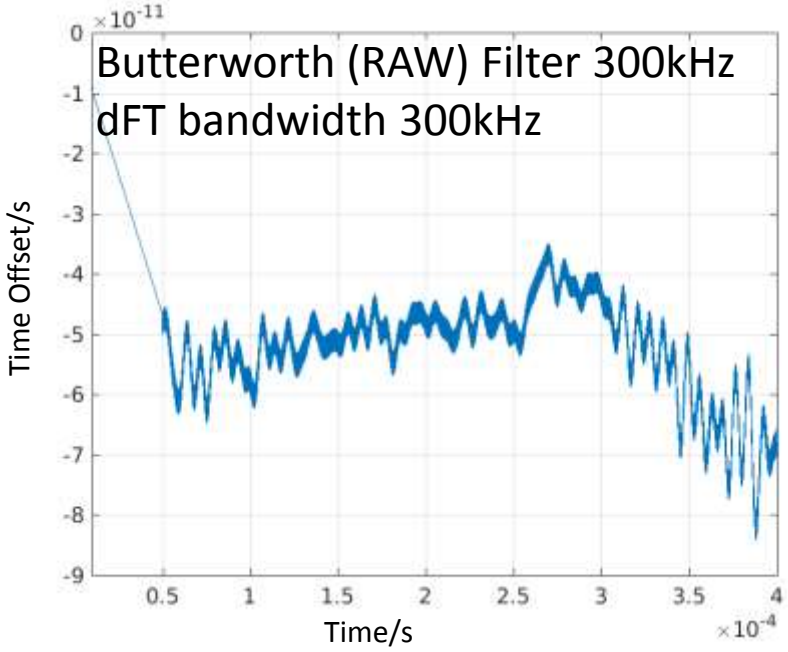
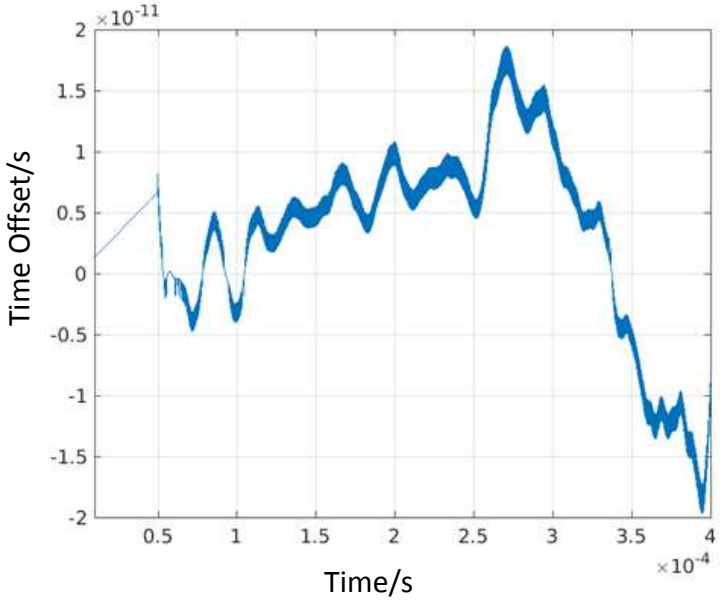




Muon Transit Phase Detection

- At previous meetings, tests showed good random walks in the reconstructed signals BUT
- Some variation in the systematic offsets
- The majority of the MTA tests did not attempt to hold the cavity on resonance
- Rather the drive amplifier followed the natural tuning of the cavity as the cavity temperature evolved
  - Freq. shifts over 32 valid datasets (i.e. no valve/cavity arcs) of ~4 kHz noted
- MICE will not run like this
- New analysis approach, first perform a very precise dFT, then use this to centre all freq sensitive processing
- Significantly reduces the offsets

Butterworth (RAW) Filter 300kHz
dFT bandwidth 300kHz
Corrected centre frequency



Summary

- Subsample method shows good performance
  - Further data from MTA tests with long record lengths also showing promising behaviour
  - Note offsets in the traces arise where the cavity amplitude is changing rapidly- this will NOT be an interesting condition for MICE

- Digitiser Hardware Status
  - 4GSa/s 2 Ch VME digitiser in hand- can record entire pulse at > Nyquist at need
  - Has 10 bit resolution (instruments used to date are 8 bit)
  - Can be programmed to run with 40MHz external clock (shared by the TDC's)
  - Work required to capture waveforms at 1Hz at whatever subsample rate we choose
    - 12.5MSa/sec or 25MSa/s seem likely candidates

- TDC hardware status
  - 300MHz Discriminator available and running tests (others are available)
  - Spare MICE TDC is at Strathclyde and installed in VME crate
  - VME bus on crate at Strathclyde now communicating with TDC- thanks to Ed

- Integration
  - Acquisition software routines need to be produced
  - Clock required to sync TDC's and digitiser
  - Trigger alignment needs to be done between TDC's and Digitiser
  - Bench tests using Arbitrary Wave Generators and 50ps transient generators