Cavity/Muon timing

- Need
  1. Cavity phase and amplitude measurement.
  2. Cavity phase for each Muon.
     - Unambiguous phase assignment for each particle.
     - Muon phase can be calculated from experiment as long as individual muons can be bundled by RF phase for later analysis.

Cavity phase and amplitude

- Frequency of RF – 201.25 MHz
  - 1 Period of RF ~ 5ns
- DAQ: Caen V1724 fADC. 100MS/s, 14 bit. 512kS/ch.
  - One Data Point every 2 Periods, well below the Nyquist limit.

- Can original RF signal be regenerated with acceptable accuracy from undersampled digitised signal?

Undersampled Signal Processing

- 201.25GHz, recorded on oscilloscope at 40GS/s.
- Data thinned to give waveforms sampled at 1GS/s and 100MS/s (same as digitisers used elsewhere in MICE system).
- 100MS/s for 1ms = 100k pts/ pulse.
- Fit to data
  - free parameters
    - phase and amplitude
  - frequency restricted +/- 50kHz (+/-1kHz @ limit)
- Yet to be proven.
- Ultimate accuracy limited by pulse length.
  - 1ms pulse implies 1kHz accuracy on frequency.

Cavity/Muon phase:

Digital low level RF Control

- To **control** and regulate cavity amplitude and phase angle during the RF pulse. Based on LBNL LLRF4 board.
- Target 0.5 degree phase, 1% amplitude
- Systems in use already with EPICS control, feedback, feedforward, resonance control etc
- Results obtained (ALICE)
  - 1 Year of operations. 2 failure conditions
  - involving RS232 communications problems.
  - – Flat top Phase RMS error 0.04 degree
  - – Flat top Amplitude RMS error 0.2%
- Ramped pulse structure to limit reflected power - tested on bench with 1.3GHz cavity.

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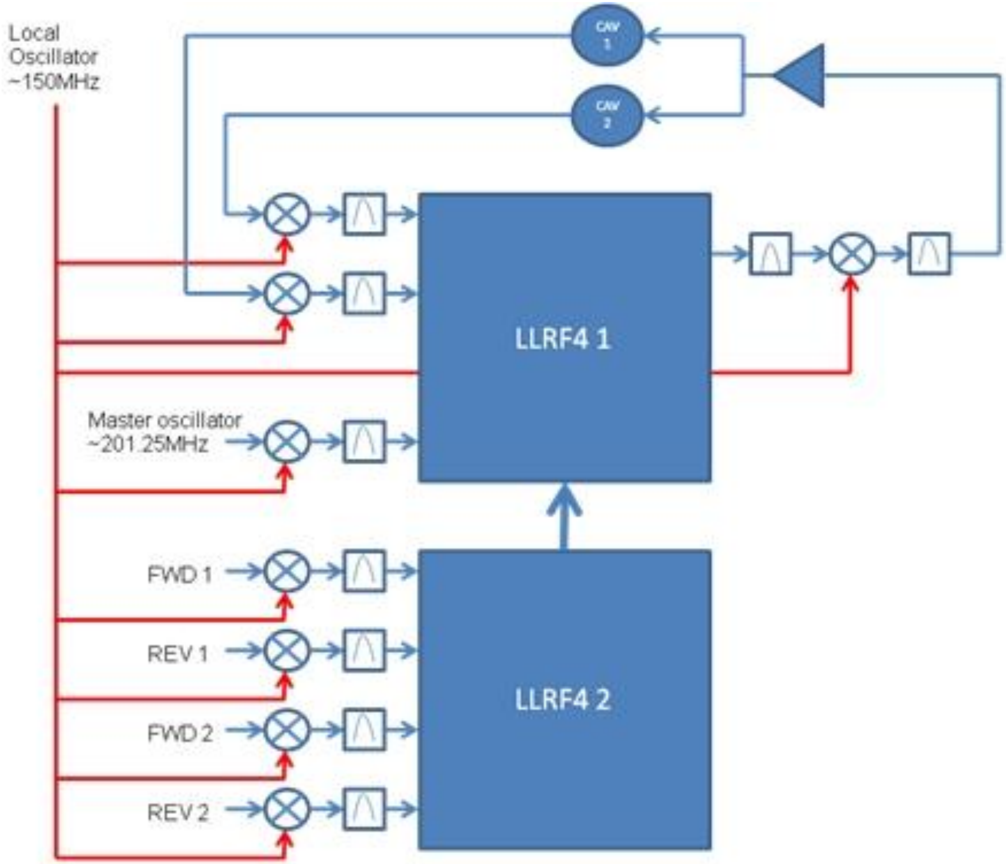
Digital LLRF

- Master oscillator (MO) at 201.25MHz, derived from 10MHz clock.
- MO has fixed phase relationship to 10MHz clock.
- Does not measure phase or amplitude.



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Muon/Cavity phase measurement

- Digitise both cavity sample signal and LLRF master oscillator.
  – Determine cavity phase wrt master oscillator.
- TDCs are time corellated using direct external clocking or PLL locked to either external source or internal @ 40MHz.
- Use TDC timing signal to phase lock digital LLRF master oscillator or vice versa.

TOF Timing Circuit

University of Strathclyde Science

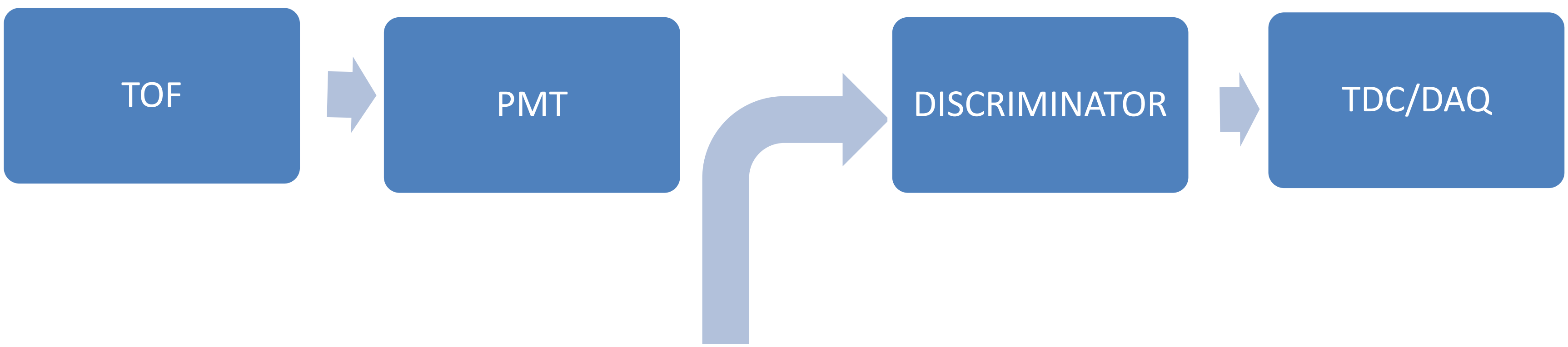
TOF → **PMT** → **DISCRIMINATOR** → **TDC/DAQ**

TOF	PMT	DISCRIMINATOR	TDC/DAQ
Particle Arrives at TOF – Scintillator emits Photon(s)	Photon arrives at PMT – Output Voltage Rises	Output Voltage reaches Threshold – Logic Signal output	Logic Signal Received at TDC – Time is noted on DAQ
	Response time ~0.7ns	Variable rise time - Typically 1-2ns	25-40ps

For the TOF measurements the photomultiplier tube response time and electronics delays are not needed as the calibration is performed relative to a reference 'pixel' in the TOF

MICE

TOF Timing Circuit



- LLRF MO signal into free TOF discriminator channel -> TDC.
- Discriminator max 30MHz repetition rate.
  - Frequency min error 1kHz/200MHz x ~5ns = 0.25ps error per RF period
  - 30MHz acquisition rate max time error = 7 periods x 0.25ps = 1.75ps.
- Continuous measurement of MO phase at 30MHz sample rate.
- Fit sine wave to sample to determine phase of Master Oscillator wrt TDC at any given time.