Plans for delivery and commission the RF system

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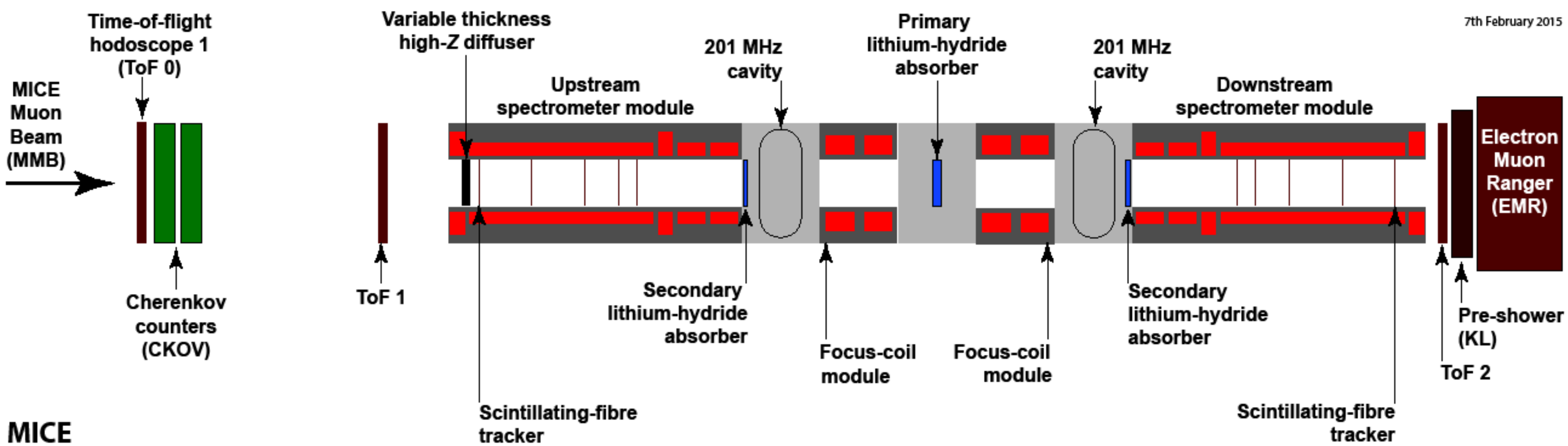
For the MICE RF team

Content

- The RF System has several Key subsystems which have been addressed in other talks
  - RF Cavities and Cavity Modules
    - Progress on the tests at the MTA discussed in the second paper
    - Cavity modules addressed in third paper
  - RF drive and distribution system
    - Plans for test, delivery and installation of amplifiers will be addressed here
      - Encompasses development of remote control (2nd talk) and LLRF control (final talk)
  - Cavity tests at RAL
    - Opportunity for a full system test
    - Commission all major components before assembly in beam line
  - Muon-RF phase determination
    - If time permits

MICE High Power RF systems

- MICE HPRF system requirements have changed
  - Fewer cavities, no coupling coil
  - Required operational date on the beamline is Summer 2017
    - Requires early commissioning of the hardware: Starting Aug 2016
  - Enables demonstration of ionisation cooling with re-acceleration
  - First results complete before end US fiscal year 2017
- It is relevant to review the timeframe and resources required to deliver this system



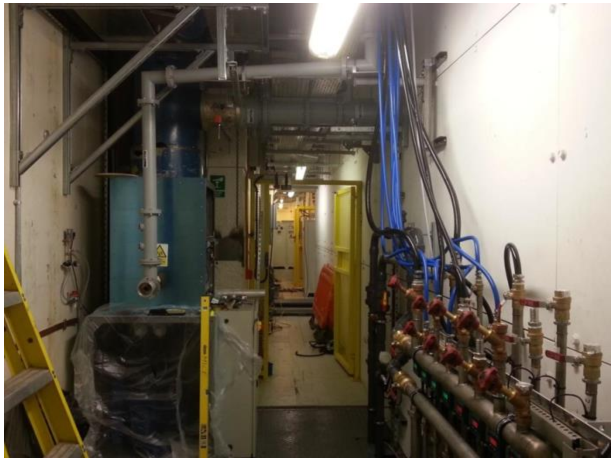
MICE High Power RF drive systems: Commissioning

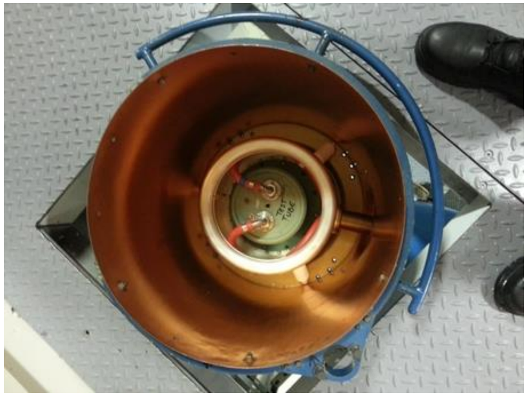
- 2MW peak output from RF drive amplifiers, are unchanged
  - First triode amplifier proven and installed at RAL
  - First tetrode amplifier also proven with pulsed power modulators
    - These are now back at Daresbury

- Commissioning System No. 2
  - Recommissioning of tetrode pre-amplifier no. 1 underway at DL
    - Operated at 100kW in the past two weeks
  - This will be used to commission triode No. 2 with first modulators
    - Mechanically refurbished triode no 2 is now installed in test facility
    - Requires electrical work to finish
  - Tetrode No. 1 will be replaced by tetrode no 2 by end of year
    - Tetrode no 2 also primarily requires electrical completion
  - Remote control system no. 1 will be implemented in control rack by end of year
  - 2nd Triode and Tetrode amplifiers operating with 1st control rack and modulators by end 2015
  - 2nd Triode and Tetrode Amplifiers operating with 2nd modulators and control rack by end Summer 2016

MICE High Power RF systems: Tim Stanley

Triode No. 1 at RAL





Triode No. 2 Completed Mechanical Refurb at Daresbury

Tetrode No. 1 Re-commissioned at Daresbury Lab

MICE High Power RF drive systems: Installation and Test

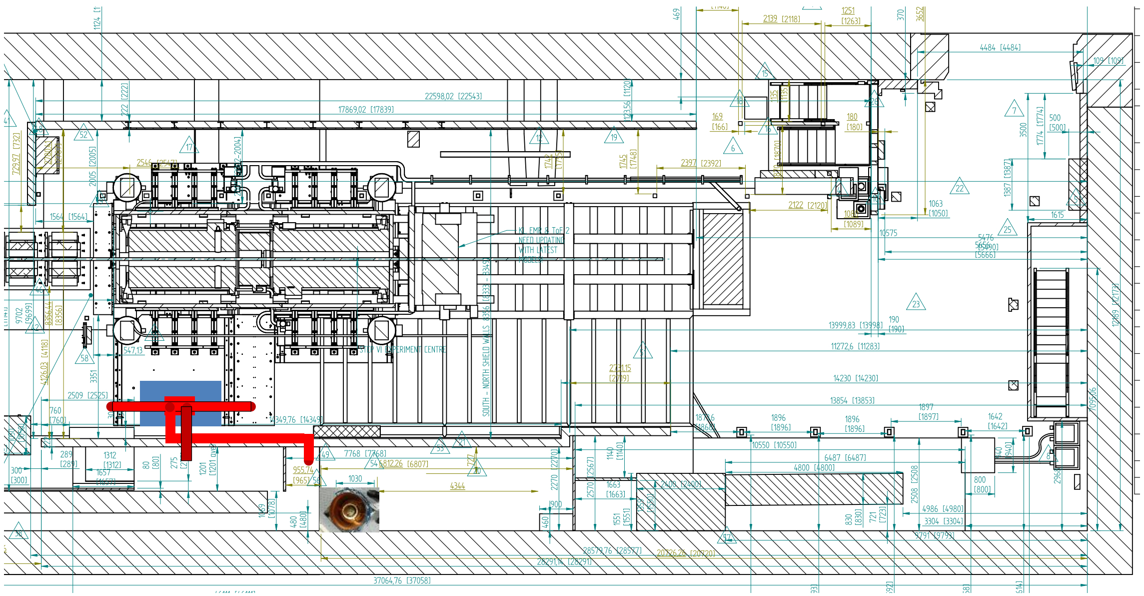
- Amplifier System No. 1
  - First triode remains installed at RAL
  - Reinstall Tetrode No.1 with Modulators No.1 and control racks No. 1 Spring- Aug '16
    - Build on previous installation for TIARA tests
    - Note there may be some conflict with key people required for installation at RAL and commissioning at DL
    - Will require mechanical modification to the Mezzanine
  - Prove with 1 Month of test operation into resistive loads

- Amplifier System No. 2
  - Project completion of Daresbury proving trials by Summer' 2016
  - Installation can commence from July '16 to Jan '17 (preliminaries need not await July '16)
    - Build on experience from installation of system No. 1
    - Will require new wiring 'loom' installation, additional cooling water panel and mechanical modification to the Mezzanine
  - Prove with 1 Month of test operation into resistive loads

Cavities: Pre-Installation

- Cavity Module No. 1: Arrival and Installation
  - Assumed to arrive under purge and fully assembled May ‘16
    - Assume cavity will not require any further baking
  - In advance, auxiliary systems will be prepared in MICE hall
    - Clean room: Essential in case any intervention is required
    - Independent cooling loop for each cavity with tight thermal regulation
  - LLRF tests to verify safe transport and arrival
  - Install cavity next to shield wall opposite U/S SS, special distribution network
  - Install vacuum pumps and pump cavity ready for operation late Jun 2016 (1-2 months)

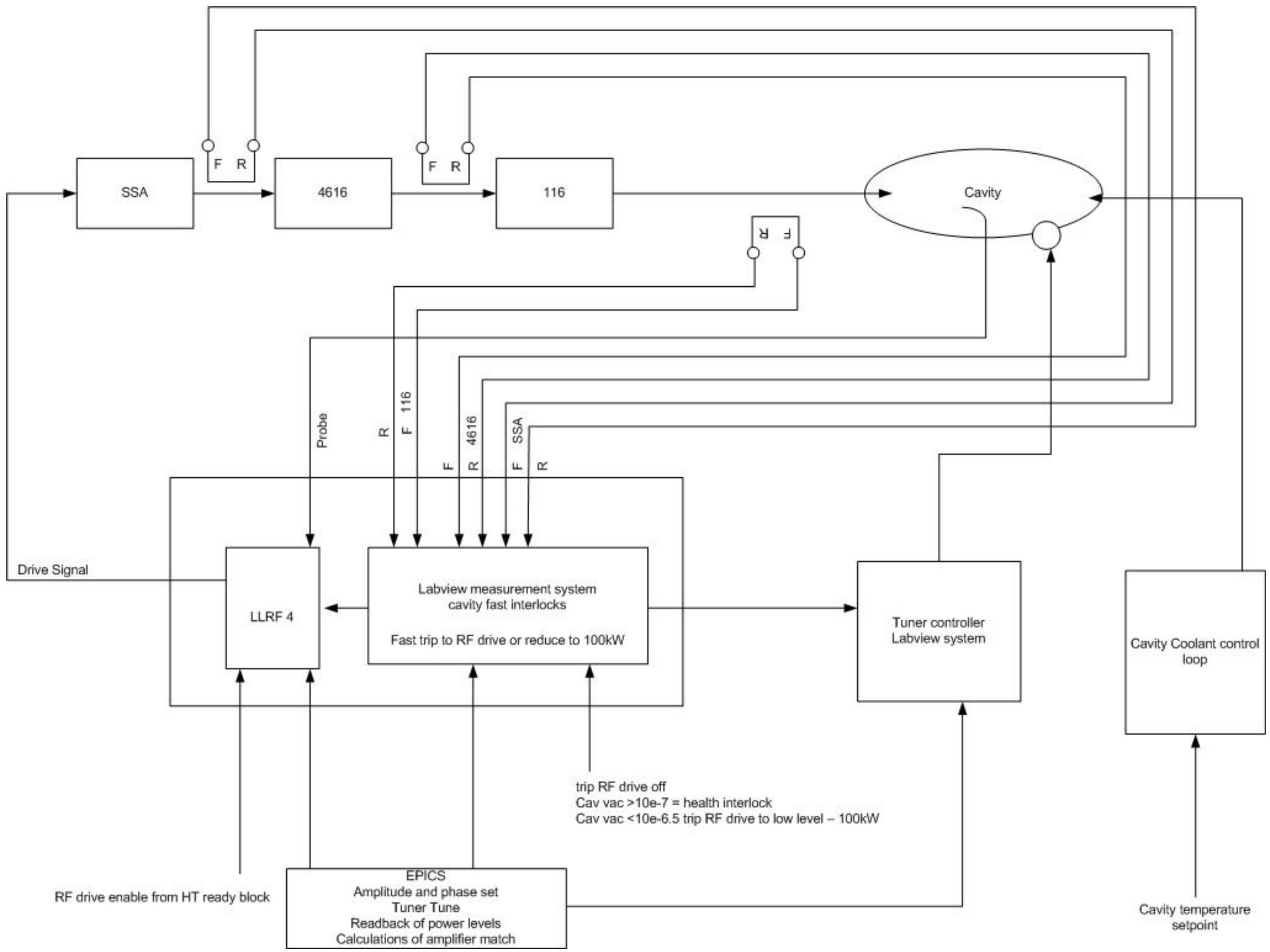
- Cavity Module No. 2: Arrival and Installation
  - Assumed to follow same pattern as Cavity module No. 1 with object of completion at Oct 2016



Cavities: Pre-Commissioning

- Pre-requisities
  - RF system No.1 with full remote controls is expected to be available in July 2016
  - Cavity No 1 expected available by June 2016
  - LLRF tuner control and RF closed loop control system expected by Summer 2016
  - Installation of RF power feeds to the test point (shield wall opp. U/S SS)
- HPRF Tests of Cavity No. 1
  - Initial tests on a single cavity, using drive system No. 1
  - Aug '16- Oct '16, est 2 months for complete tests
- HPRF Tests of Cavity No. 2
  - Oct '16- Dec '16 using drive system No. 1
  - Leave in situ until last possible moment
  - Opportunistically test with drive system no. 2 if timing is good

LLRF Drive and Cavity Control System: Andy Moss



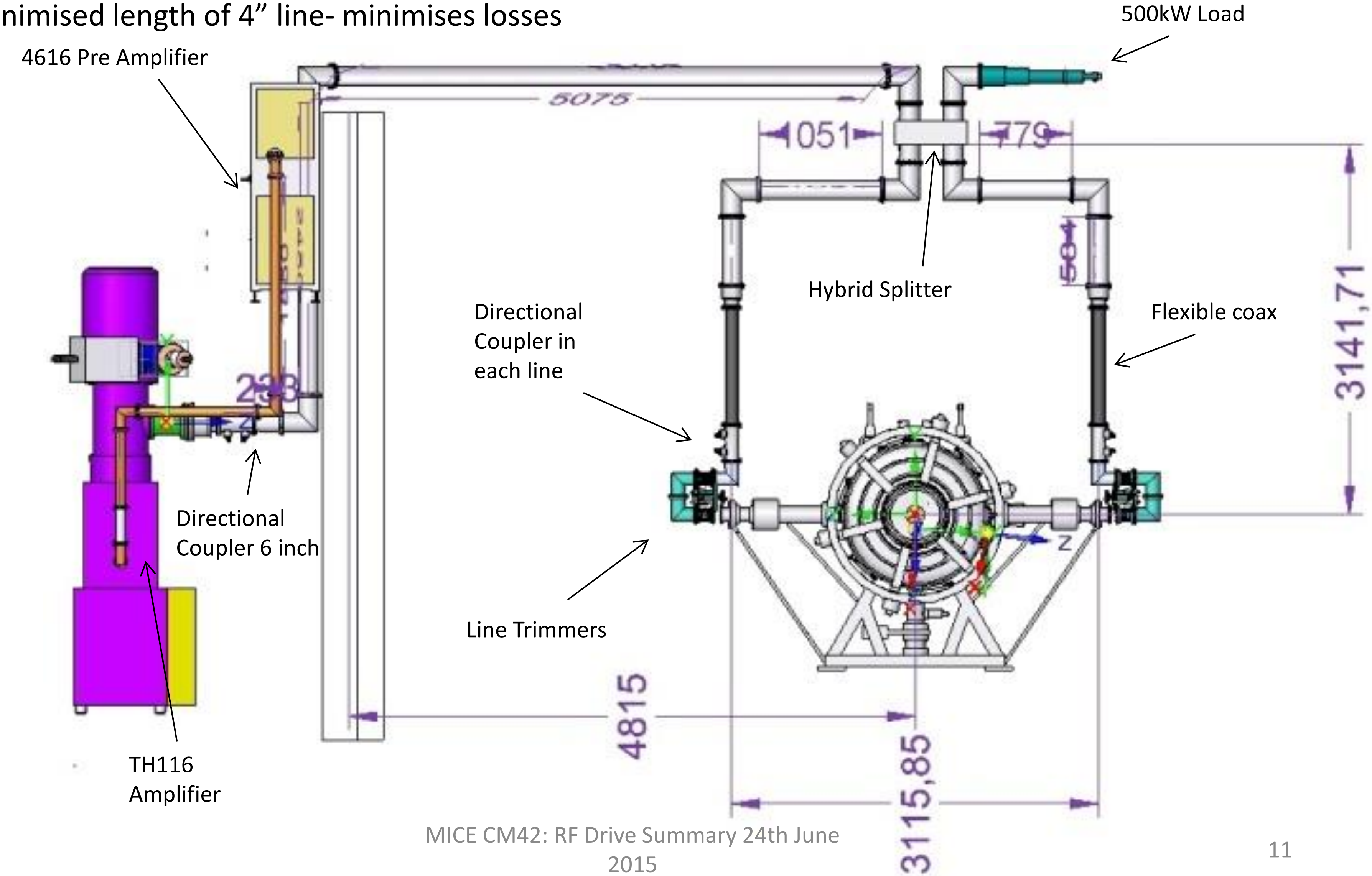
Cavities: Installation

- Pre-requisities
  - Completion of tests on two cavities with RF amplifier No. 1
    - Ideally also pre-commissioning tests with Amplifier No. 2 and Cavity No. 2
  - After tests cavities left under purge N_2 gas
  - Removal of the STEP IV yoke and completion of the absorber, spool pieces
  - Build of floor plates, mechanical integration components
  - Installation of final RF distribution network (planned for Aug '16- Feb '17)

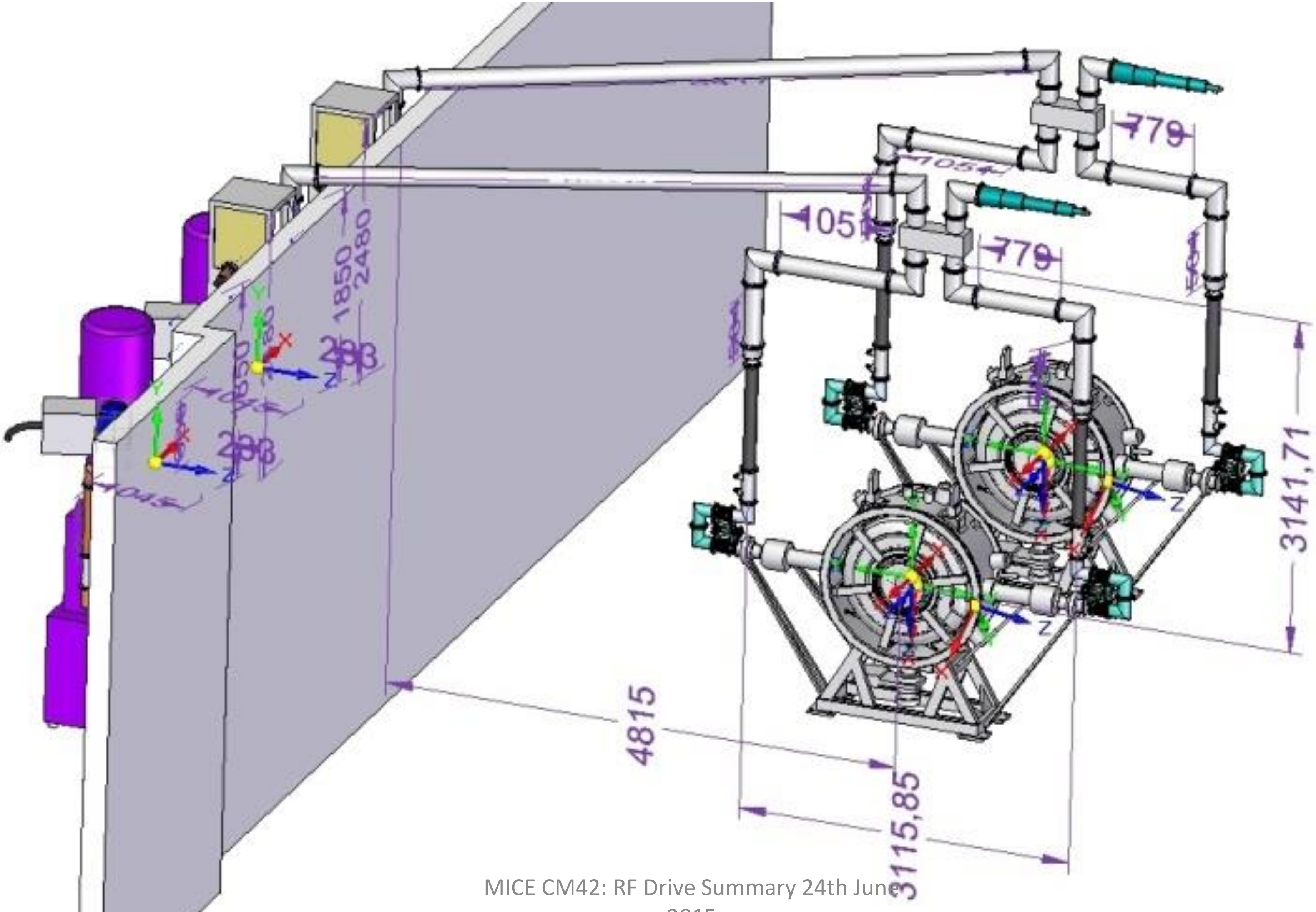
- Procedure
  - Cavities should be left under purge until the last possible moment.
  - Absorber and spool sections 'beam line vessel' should be pumped separately and left under purge
  - When final installation is imminent, the 'beam line vessel' cavity gap be opened and the apertures blocked with thin plates
  - When ready, the end plates of the cavity modules should be removed, replaced with thin plates for installation
    - Cavities immediately installed in the beam line vessel
    - Immediately 'rough pumped', then HV pumped
  - Starting by Feb '17 and planned complete early March 2017, validate with LLRF measurements

RF network: Alan Grant

- Simplified distribution network- feasible to route overhead
- Off-centre mounting of hybrid takes up phase shift
- Orientation of load arbitrary- align with the 6” distribution line and share mountings
- Minimised length of 4” line- minimises losses



RF network



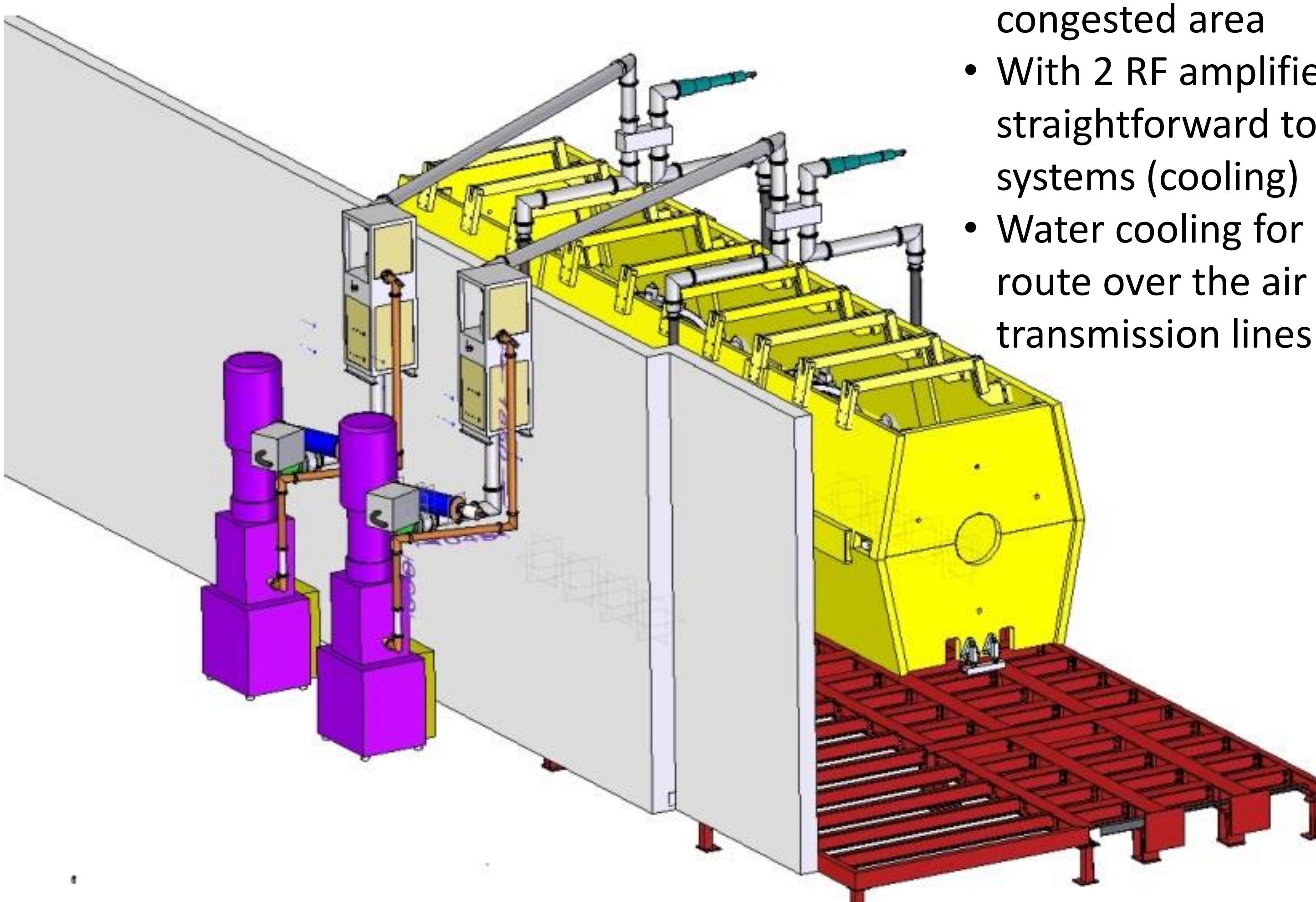
Cavities: Commissioning

- Commissioning without B field
  - Cavities should be HPRF tested on beam line before yoke is complete
    - In case any intervention is required
  - Estimate <1 month operation of both cavities together, so completion by April 2017

- Commissioning with B field
  - Requires completion of Yoke and re-commissioning of all magnets
    - Note ONE magnet only will be added to the STEP IV set
    - Yoke plate final installation est ~ 1 wk
    - Commissioning of magnets will benefit from the STEP IV plan
      - Outlined by Jaroslaw yesterday
    - Tests of the cavities with magnetic field and all systems April 2017, say 2wks- 1mnth
      - In parallel with magnet commissioning if possible

RF network

- Load on each splitter to absorb unbalanced reflections
- Retracted crane hook clears coax over the wall.
- Support from present ‘shield wall’ and yoke supports



- 2^{nd} amplifier moved to 3^{rd} position behind wall to ease installation in congested area
- With 2 RF amplifiers now relatively straightforward to place auxiliary systems (cooling)
- Water cooling for load will need to route over the air gap on the transmission lines

RF Phase determination: Alex Dick

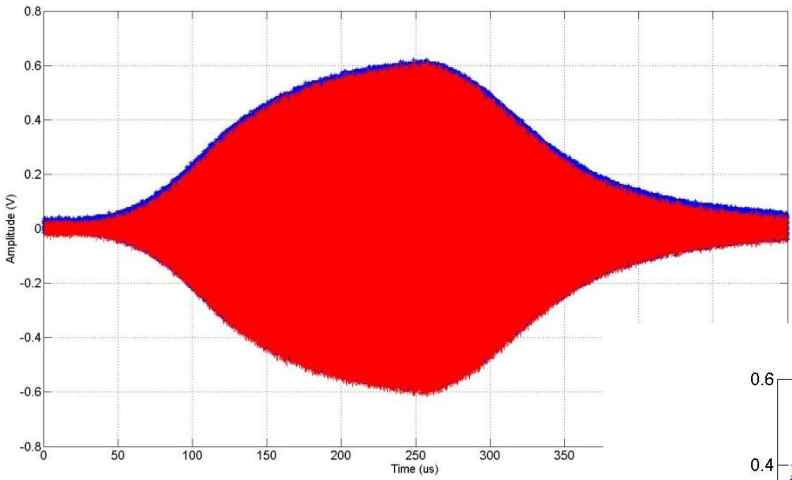
- Need to be able to select particles for analysis by their RF transit phase
  - Allows the ‘bundling’ of particles for coherent analysis
  - i.e. As if we are considering the interactions of a real particle ‘bunch’

- Particle transit time determined by ToF detectors- used in difference measurements
  - ToF resolution ~50ps
  - Time is not directly referenced to external clock
  - Closest ToF is ~2.5m upstream of 1^{st} cavity

- Cavity transit time inferred by the ToF transit time and the tracker measurement of momentum
  - Tracker resolution, p_z ~ 200MeV/c is Δp_z ~+/-1.3MeV/c
  - For 2.5m gap transit delay is ~9.6ns +/- 15ps
  - Combining ToF resolution and Momentum projection resolution ~ +/- 52ps
  - Desire to know RF phase to better than 0.3 of this ~ 20ps

Demonstration of subsample approach

- Traces of cavity fill from MTA tests
- Test viability of subsampling the AC waveform- suppress data management by orders of magnitude
- Reconstructing signal in Fourier domain and comparing signals (Blue is Raw, Red is DSP)

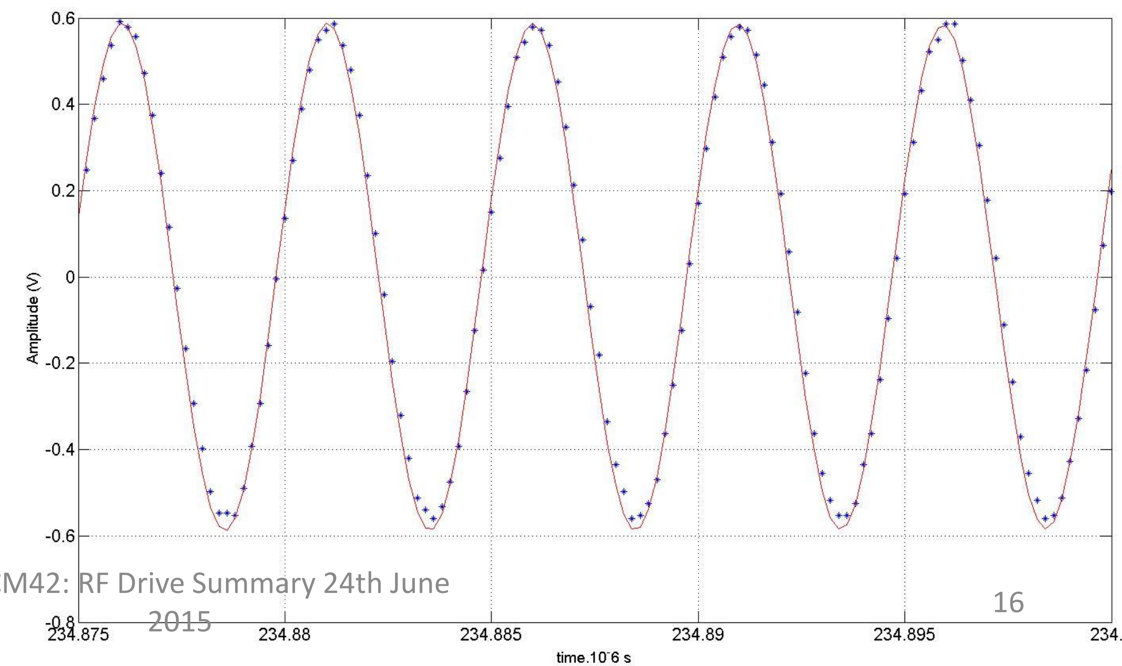


- Note suppression of DC bias
- Note DSP has effective filtered the signal
- Suppressing noise and instrument artefacts

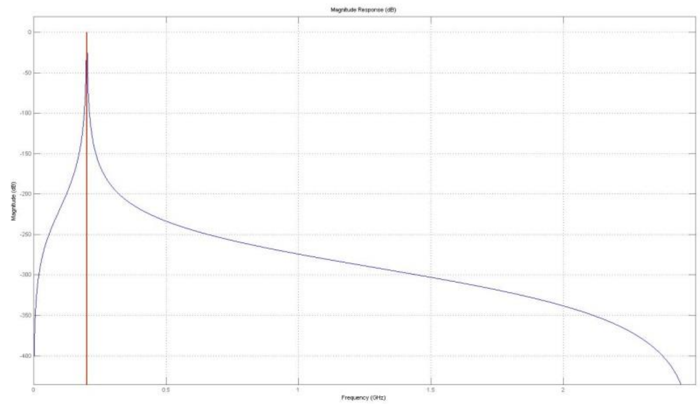
- Zero crossing offsets between Raw and DSP?

  Range from 10-75 ps

  Not good enough



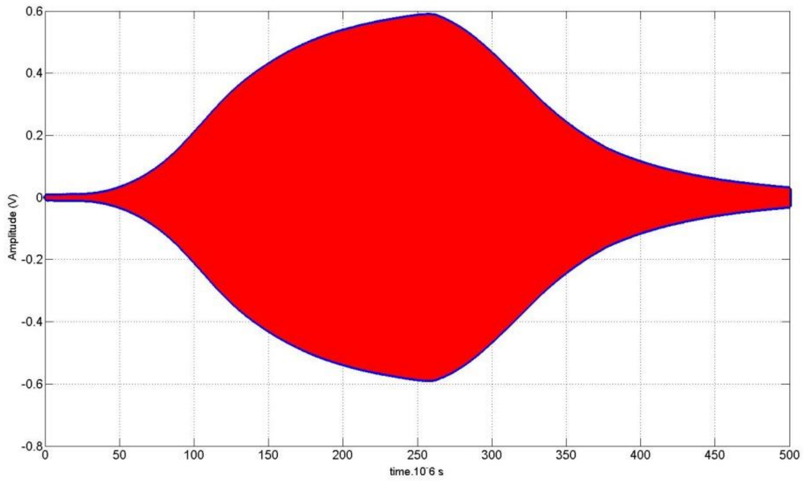
Filter: Suppress noise and digitiser artefact

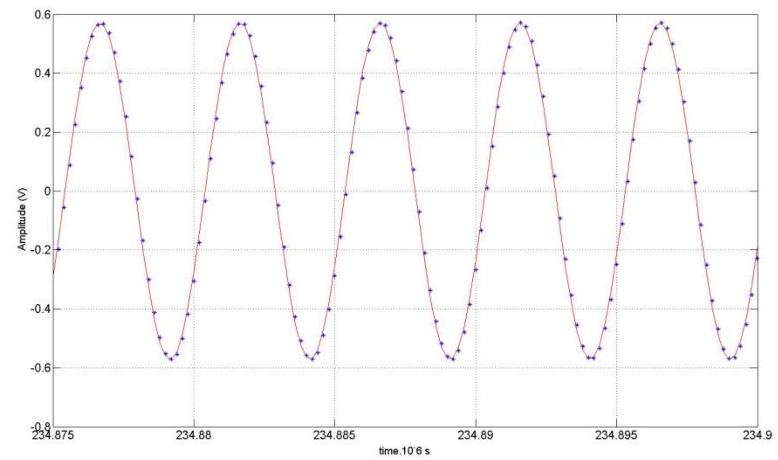


Butterworth Filter with flat 2MHz passband at 201.25MHz

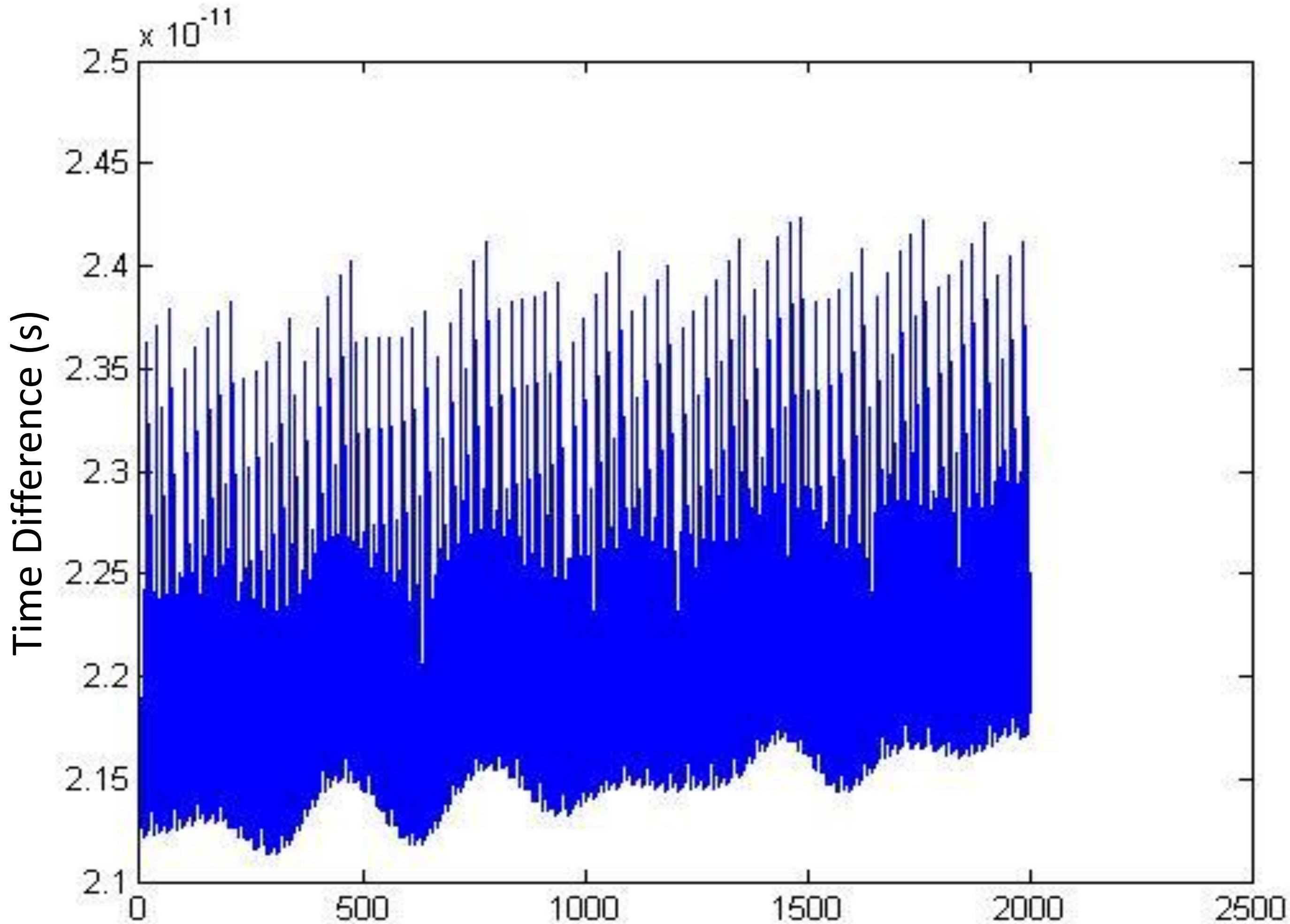
Very precise reproduction of signal

Much less variation in phase difference ~1-2ps (between original and reconstructed signals)





Difference between Original and Reconstructed signal Zero Crossings (Filtered)



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Hardware: Digitisers

- Will be important to provide clock synchronisation and trigger- i.e. t=0 synchronisation for ToF TDC's and RF instruments
  - t=0 can be defined by an external trigger to zero all timebases
  - Just before accelerating gradient reaches maximum

  OR
  - Just before start of RF pulse
  - Use a pulse generator to provide 40MHz clock, and provide trigger by logical AND between clock and trigger pulse- should sync start of timebases

- CAEN V1761 have external clock drive for acquisition rate
  - 10 bit rather than 8 bit units currently recording MTA data
  - Facilitate interfacing with 40MHz clocks of TDC's (requires programming of the clock controller)
  - Need to understand trigger jitter statement?

Hardware: TDC approach

- This is currently planning to use the TDC (CAEN 1290) that are already being used to record the ToF signals
- RF signal driving discriminators, use TDC time stamps to find cavity 'zero crossings'
  - 25 ps bin size
- Same electronics enhances confidence that any drift in time accuracy will be similar
  - Unfortunately LeCroy discriminators seem problematic at 200MHz
  - Input impedance wanders with frequency, at 201.25MHz, 98+j68Ω
  - Could be matched with L-branch network, but still doesn't fix rate problem
- RF signal amplitude and spectrum is very well known: no need for a CFD
  - Threshold trigger system is much less complex
  - Quote obtained from Phillips Scientific for updating and non-updating leading edge discriminators
  - 3ns double event resolution and 300MHz bandwidth, <30ps jitter

Summary

- Drive Commissioning Timetable
  - Amplifier No. 1 with automation installed and operational by Aug 2016
  - Amplifier No. 2 with automation installed and operational by Feb 2017
  - LLRF and cavity control systems operational by Aug 2016

- Cavities
  - Arrival May 2016
  - Cavity no. 1 ready for standalone tests by end June 2016 : Compete by Oct 2016
  - Cavity No. 2 ready for standalone test by Oct 2016 : Complete by Dec 2016
  - Cavity installation to beamline Mar ’17
  - Installation of distribution network by Feb ‘17
  - Tests of the cavities without B-field late March /early April
  - Tests of Cavities with B-field, May 2017

- Muon Timing
  - Subsampling techniques appears to work – filtering the signal is important
    - Requires resilience analysis
    - Digitiser selection needs to be complete
  - TDC technique- suitable discriminators identified
    - All other hardware in hand