Status of the MICE RF System

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For the MICE RF team

Content

- Distribution network
  - Detailed mechanical design work complete
    - Ensures matching of electrical lengths
  - Required parts identified and isolated from NSF procurement
    - Ready for advanced RF tests
  - Hangers designed and fabricated
    - Delivered to Daresbury- ready for test assembly

- Status of RF drive system
  - Progress in the testing of the amplifier chain
  - Plans for delivery and installation of amplifiers
  - Development of RF Controls & Monitoring systems
  - Development of LLRF

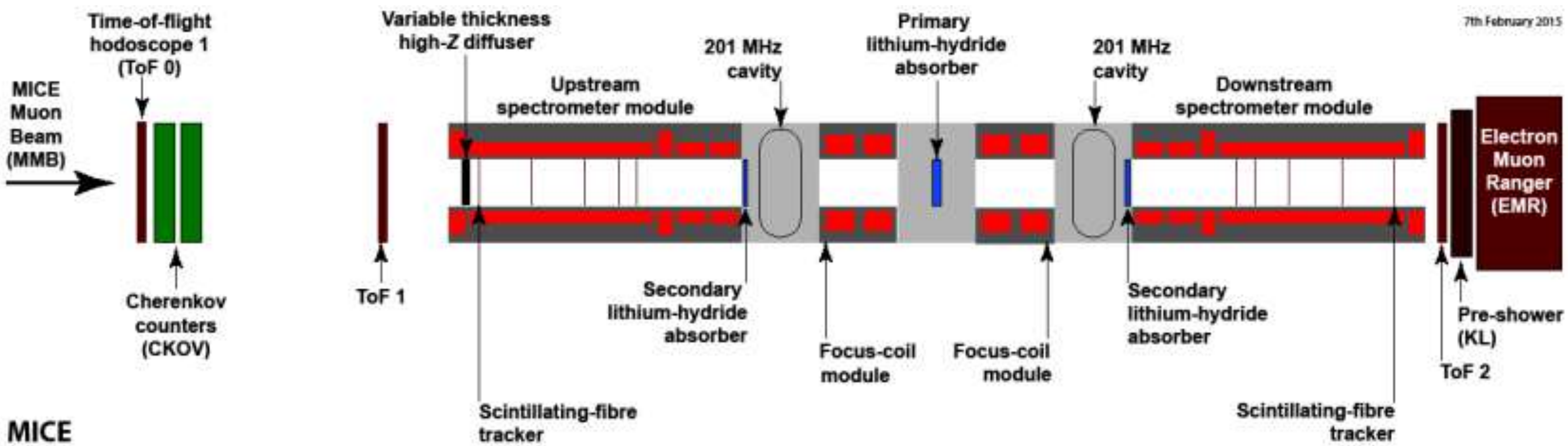
- Status of cavity systems
  - Test status and production of final modules

- Muon-RF phase determination
  - Subsample technique demonstrates required accuracy

- Plans for a full system test at RAL

MICE High Power RF system: Requirements

- MICE HPRF system requirements have changed
  - Two cavities, driven by two RF power amplifiers- 2MW output each
    - Estimated gradient 10.3 MV/m- partial restoration of axial momentum
      - Allowing for realistic LLRF overhead and losses
    - Bracketed by two thin LiH absorbers, sandwiching main absorber
  - Determine RF phase on transit of each muon
  - Required operational date on the beamline is Summer 2017
    - Potential to pre-commission hardware: Starting Aug 2016
    - Exploit proposal for the RF cavities modules delivered UK Spring 2016



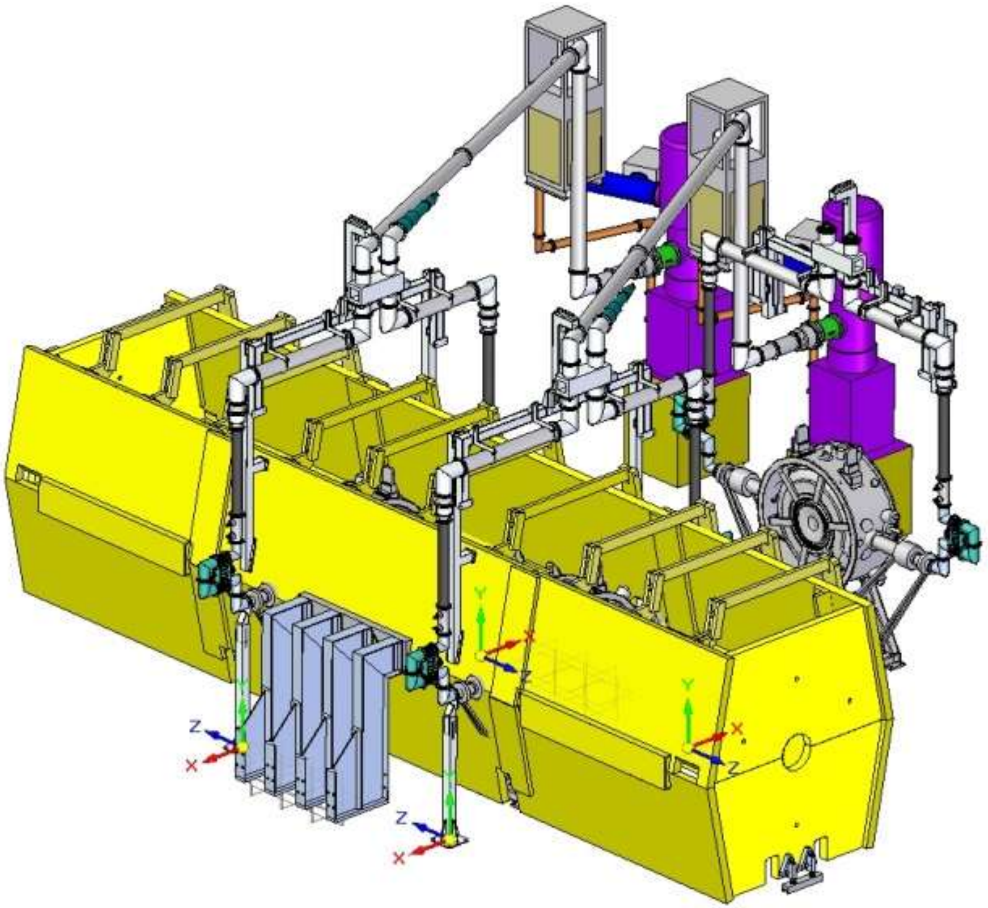
RF Distribution Network

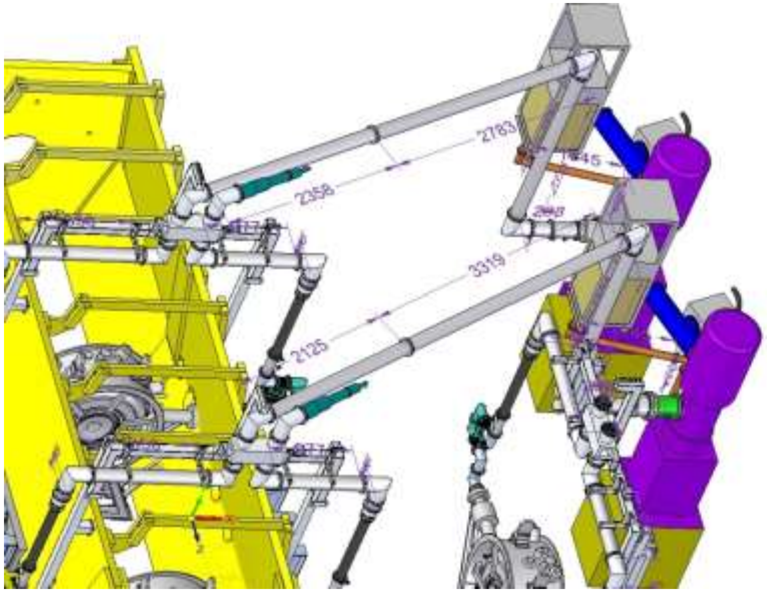
- Must Support 2MW in 6” line and 1MW in 4” line with full reflect
  - 4” lines rated to 1.12MW at 1 atmosphere in dry air
  - Therefore will be pressurised by SF_6
    - 1.5 bar gives safety factor of 2 in power handling (c.f. 1MW and full reflect)
    - Will be treated as pressure vessels
  - Some of the 6” and 4” line from the NSF MRI procurement will be modified
  - All components/devices will be drawn from the NSF procured stock

- Must deliver power to two cavities installed in line AND one offline test positions
  - Estimated <10 % loss in transmission line
  - Power delivered to each cavity 1.62 MW,
  - Anticipated gradient in each cavity 10.3 MV/m

RF distribution network

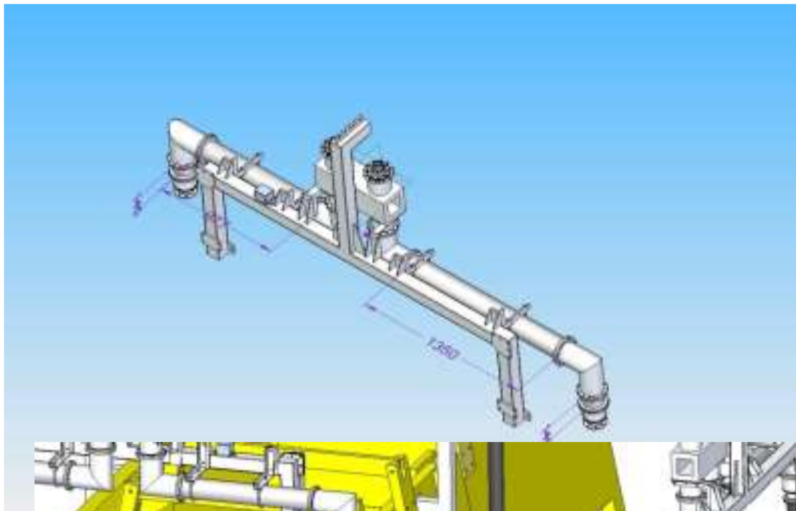
- RF network design has moved to detailed engineering
- Off-centre mounting of hybrid takes up phase shift- ensures equal length lines
- Orientation of load aligns with the 6” distribution line, shares mountings
- Minimised length of 4” line- minimises losses

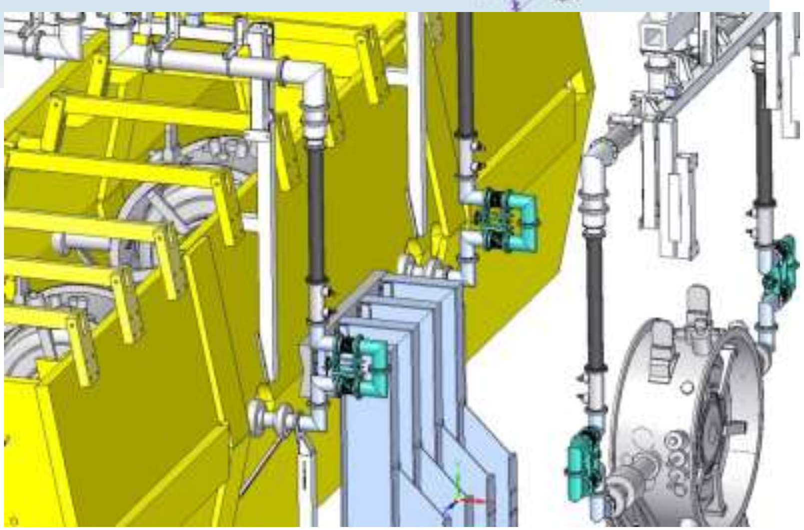




RF network

- Hanger design now complete and fabricated
  - Includes both online and offline hangers
- Support will be from present 'shield wall' and yoke





- Components now at Daresbury
- Ready for test assembly
- RF components identified and ready for measurement

RF Drive System

- First Amplifier Chain
  - Has delivered required 2MW at Daresbury test stand
  - Installed and commissioned at RAL autumn 2013- delivered 500kW
  - Output (triode) stage remains installed at RAL
  - Modulators and preamplifiers returned to Daresbury
    - Mechanical changes complete to output stage modulator
    - Will permit use of upgraded crowbar
  - Preamplifier recommissioned at Daresbury
    - Includes modification to the input circuit- improves reliability
    - Delivered 220kW- ready to test triode no. 2

- Second amplifier chain
  - Output stage mechanically complete- awaits electrical effort
    - Tests expected by end 2015
    - Using upgraded modulator for first chain
  - Second tetrode amplifier mechanically complete-
    - Tests planned March 2016

RF Drive System

- Modulators: System 1
  - Triode modulator presently receiving upgraded crowbar
    - Ready for tests Dec '15
  - Tetrode modulator crowbar upgrade by April '16
  - Modulators and preamplifiers returned to RAL July '16
    - After test of control rack 2- next slide
    - Will be used to drive amplifier system to test cavities in hall

- Modulators: System 2
  - Pre-amp modulators ready Aug '16
    - Commission with pre-amplifier No. 2
  - Output stage modulators ready Dec '16
    - Commission RF system No. 2- Jan '17
  - Feb '17 system no.2 ships to RAL for installation

- Resources
  - Development of these modulators requires significant Electrical Engineering Effort
  - Support from ISIS EE will help- tetrode grid modulators to MICE duty requirements

RF Drive System

- Controls system
  - Development of controls racks is underway by Daresbury Electrical Engineering
    - Based on requirements defined by RF team
    - Will review controls definitions in two weeks time

  - 1st Demonstration of remote control-
    - Control rack No. 1 tested Daresbury May ’16
    - Using Modulator System 1 and Amplifier chain No. 2
  - 2nd controls rack commissioned
    - Test at Daresbury July ‘16-
    - Prior to transport of 1st modulator system to RAL

  - Integration of RF control subsystem to MICE controls
    - Primary RF controls interfaces will be by EPICS
    - Facilitates integration to MICE controls
    - Interface points of LLRF subsystem to RF controls to be defined in detail
      - See later slides
    - New resources at Imperial being brought to support this integration

LLRF System

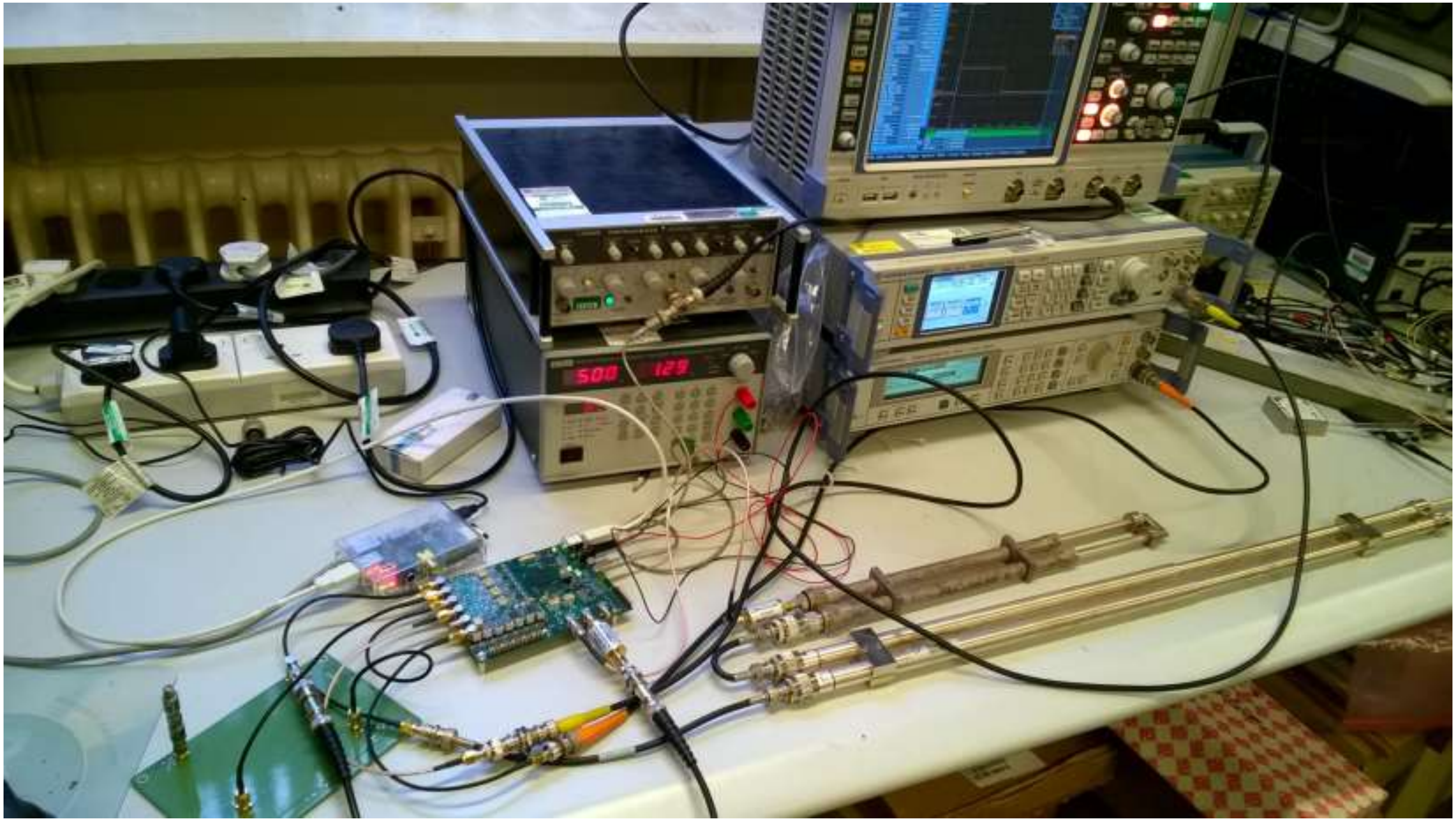
- Effort has been invested to address resource issue reported at last MPB
  - FPGA LLRF programming expertise departed from DL spring ‘15
  - Sought (and received) support from ISIS RF team-
    - ISIS have prioritised MICE LLRF development
      - Possible if MICE system is similar to ISIS requirements
    - Bob Anderson @ ~ 100% effort
    - MICE are very appreciative of ISIS support
  - 201 MHz LLRF system operating in RF lab at RAL
    - Based on Daresbury Digital LLRF system planned for MICE
  - Plans in place for LLRF development
    - First system (control one cavity) ready by April 2016
    - Second system (controls two cavities) ready by March 2017
    - Two modes:
      - Open Loop ‘tune up’ mode- with external source under manual control
      - Closed loop single frequency operation once cavity on tune
  - Daresbury have appointed new RF FPGA specialist

LLRF System

- Housekeeping system for ‘slow’ control and monitoring of the RF system
  - New Daresbury appointment has expertise in NI systems
  - Similar to NI system in use at MTA- in particular tuner control will carry over
    - Hardware specified and priced- awaiting purchase
  - Will monitor:
    - fwd and refl power, cavity pick up signal
    - spark events,
    - vacuum pressure
    - Coolant flow and temperature
    - Tuner pressure
  - Control cavity tuners
    - Fixed hold and closed loop modes
    - Selected during open loop set up of cavity
  - Decisions on shut down in event of sparks
  - Monitor relative phase of cavities
  - Provide ‘trigger’ signal to DAQ that system is nominal (i.e. full and correct phase delay)

LLRF System

- Plan to operate at 201.249MHz closed loop
- 9/11 of LLRF clock at 245.971 MHz
- Prototype operating in ISIS injector group RF lab- adjusting phase to compensate for trombones



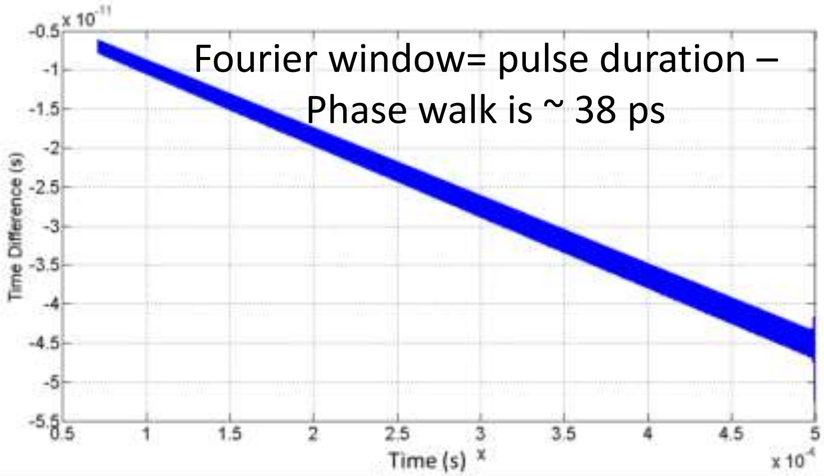
LLRF System

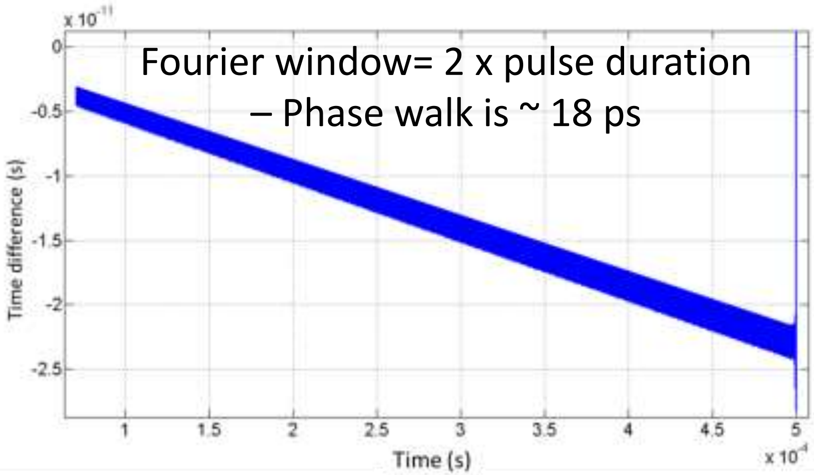
- Test panel data operating at 201.249 MHz closed loop
- Deliberately reduced 'speed' in the feedback system
  - Shows clearly the 'tune' at the start of the pulse

RF Module progress

- Testing in a comparable magnetic field at the MTA at Fermilab
  - Verified the surface treatment for the RF power couplers
  - Reached 13.7 MV/m with zero sparking
- Order for vacuum vessels placed
  - Completion Jan. 8, 2016
- Component parts:
  - Cavity bodies complete
  - Tuner arms complete
  - Actuators complete 30th November
  - RF power couplers complete 30th October
- Assembly of first unit to begin in early Jan
  - Cavity/tuner arm preparations beginning now
  - Clean room prep beginning now.

Update: Muon – RF Timing

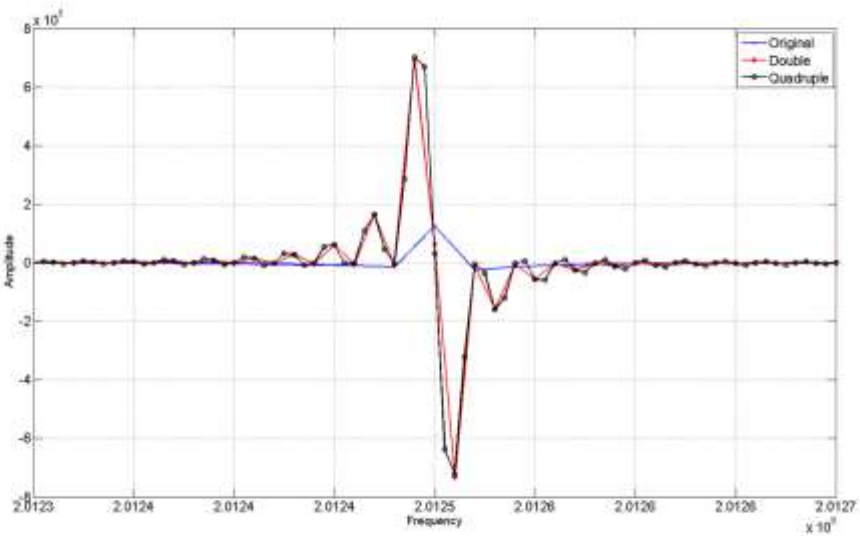




- Subsampling of RF signal desired
  - Suppress data volumes
  - Esp. at DAQ system
  - Exploits narrow cavity linewidth
  - Restore signal with Fourier Domain reconstruction
  - Shows systematic phase drift
- Phase drift associated with inadequate FD resolutions
  - Improved by artificial extension of sample duration
  - Phase drift inversely proportional to FT window duration
  - Implies require data length ~4 x greater than pulse duration

Update: Muon –RF Timing

	WALK (ps) vs FT window		
Sample Rate (MSa/s)	Sig Duration	x2	x4
4	12000	600	280
5	900	450	225
8	500	250	125
10	375	180	90
20	100	47.5	24.5
25	45	20	10
40	37.5	18.5	9
50	62.5	31.5	16.5
100	100	60	30
200	140	73	35.5



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Installation and Commissioning Programme: Cavity No 1

- May 2016: Module delivered assembled, LLRF tested from LBNL
  - Re-test tuning
    - Exercise Tuners
    - Acceptance Criteria
  - Prepare Cavity for operation June-Sept '16
    - Prepare for evacuation: pump, gauge installation:
    - Prepare cavity diagnostic systems, control systems, cooling,
    - Install in upstream space against shield wall (parallel to upstream solenoid)
      - May require X-ray shield (est ~80 microSv/hr at 3m)
    - Evacuation,
    - Install & tune overhead RF lines,
    - Retest of cavity tune after evacuation,
- Amplifier No 1 installed Oct '16
- Offline High Power RF tests Oct-Dec '16

Installation and Commissioning Programme: Cavity No 2

- Pre test prep in parallel with Cavity 1
  - Make transition to test of cavity No 2 rapid
- Will continue to use amplifier No 1: After end of tests of cavity No 1
- Installation and high power tests Expected Jan-April 2017

Installation and Commissioning Programme: Cooling Channel

- Cavity 1 install online Jan '17, Cavity 2 Install online May '17
- RF Amplifier No 2 installed Nov '16 through May '17
- Pump down and High Power Tests – No B field June '17-Mid July '17
- High Power Test with B-fields Sept '17

Resources

- Resources required recently revised
  - In light of a review held in Sept. Chair: M Palmer
    - Indicates the need for enhanced RF project resources
    - Considered both the RF and EE expertise
    - Discussed by Colin Whyte, Alan Grant earlier
      - STFC effort indicated requiring 2x increase immediately
      - Presently Tim Stanley full time support by KR, SA at fractions
      - Addition of effort of Bob Anderson and Increased effort of Saad Alsari
      - Involve Ajit Kurup on controls
      - New appointees Florian and Dumbell @ DL will contribute
  - Looking forward to commissioning cavities /amplifiers reveals conflicts
    - Requirement RF experts across two sites and with requirements to test cavities out-of-hours requires particular uplift in RF effort through ‘16 and ‘17
  - US RF expertise requested in this commissioning activity
    - Reflected in resources discussed by Peter Garbincius
    - Approx. 1.5 US Man Years allocated for cavity tests- Possibility of increasing by about 0.6 FTE

Summary

- Detail design and fabrication of distribution network
  - Components now at Daresbury for hangers
  - Ready for trial assembly
- Power Amplifier tests resumed
  - Input structure of first tetrode improved
  - 2nd Triode nearing completion
- LLRF resource issues: resolution in sight
  - Prototype system operational
  - Detailed plan for system to be built up
- RF Modules
  - Derisking largely complete
  - Component fabrication underway- assembly commences Jan '16
- Sub Sampling of the RF for Muon phase determination
  - Required accuracy is reliably reproduced on synthesised signals
  - Using enhanced scheme for Fourier Domain reconstruction
- Control/Automation requirements drafted & reviewed
  - Allows hardware to be built up
  - Additional programming expertise being brought on board
- Proposal for full system tests in mid-late 2016
  - Will debug system ahead of operation in summer 2017