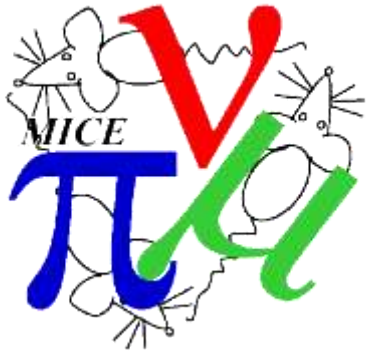
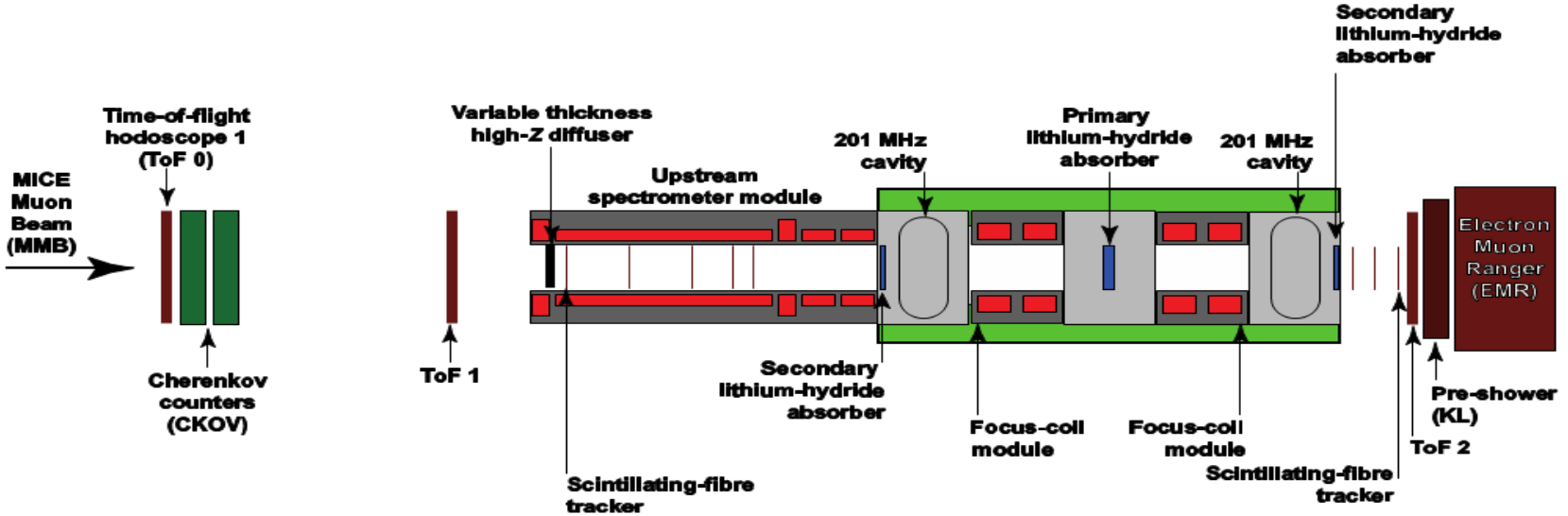



# Status of the MICE RF System

The MICE RF team

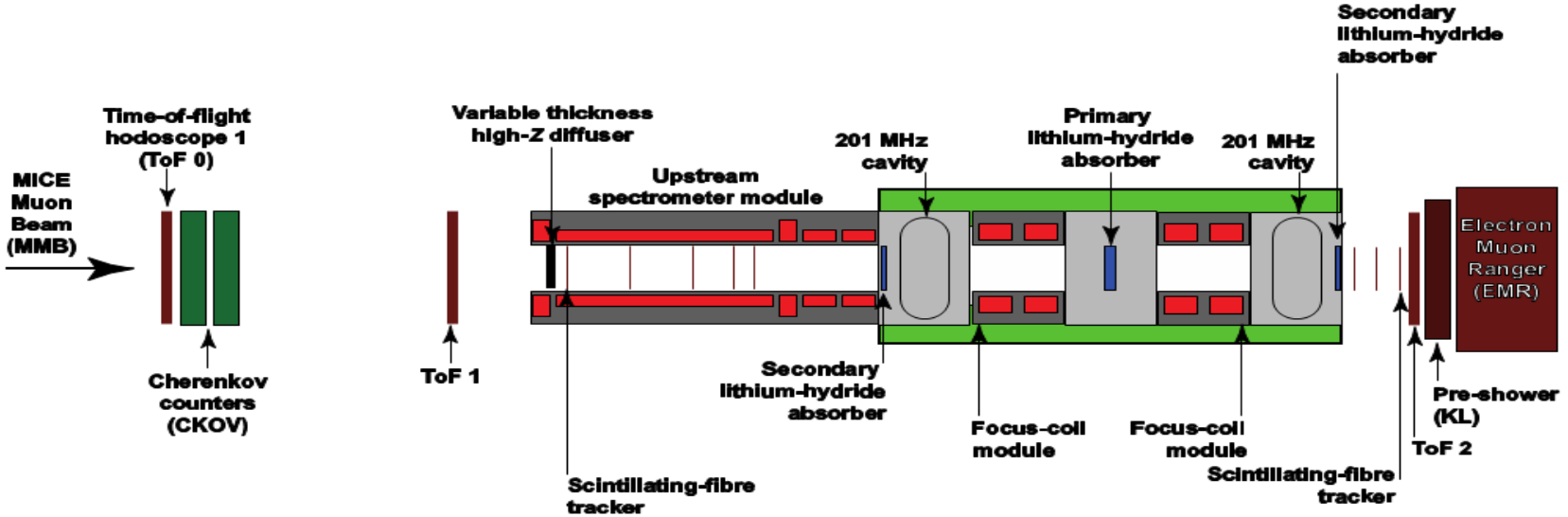
# MICE High Power RF system: Requirements

- MICE High Power RF system
  - Two cavities, driven by ONE RF power amplifier- 2MW output
    - Estimated gradient 7.2 MV/m
      - Allowing for realistic LLRF overhead and losses
  - 1st Amplifier proven and installed @ RAL(triode stage remains installed)
  - Cavity proving complete @ MTA
    - At much higher gradients (up to 14.3MV/m)
    - Cavity performance risk enormously mitigated
  - Cavity construction in hand @ LBNL



# MICE High Power RF system: Requirements

- MICE High Power RF system
  - Two cavities, driven by ONE RF power amplifier- 2MW output
  - Lower gradient means less risk/lower cost at cost of reduced $p_z$ uplift
    - Not without its own issues
    - No longer have electronic control of relative phase
    - Either predefined fixed phase setting or increments by mechanical adjustment of the transmission lines
    - Alternative: Quote received $25k US for 1.5m trombone phase shifter
  - Note: Means we lose control of the impedance presented at the amplifier

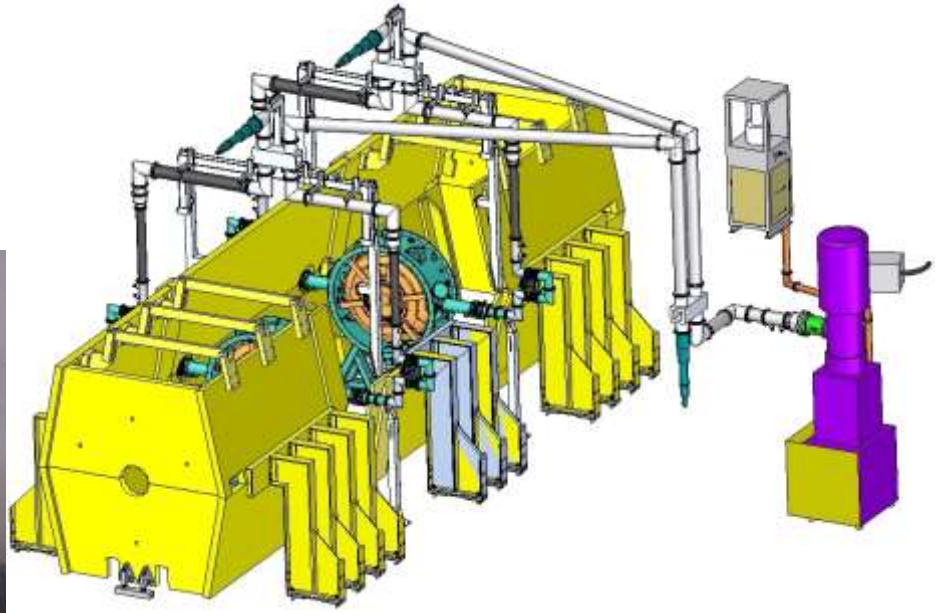


# Status Summary

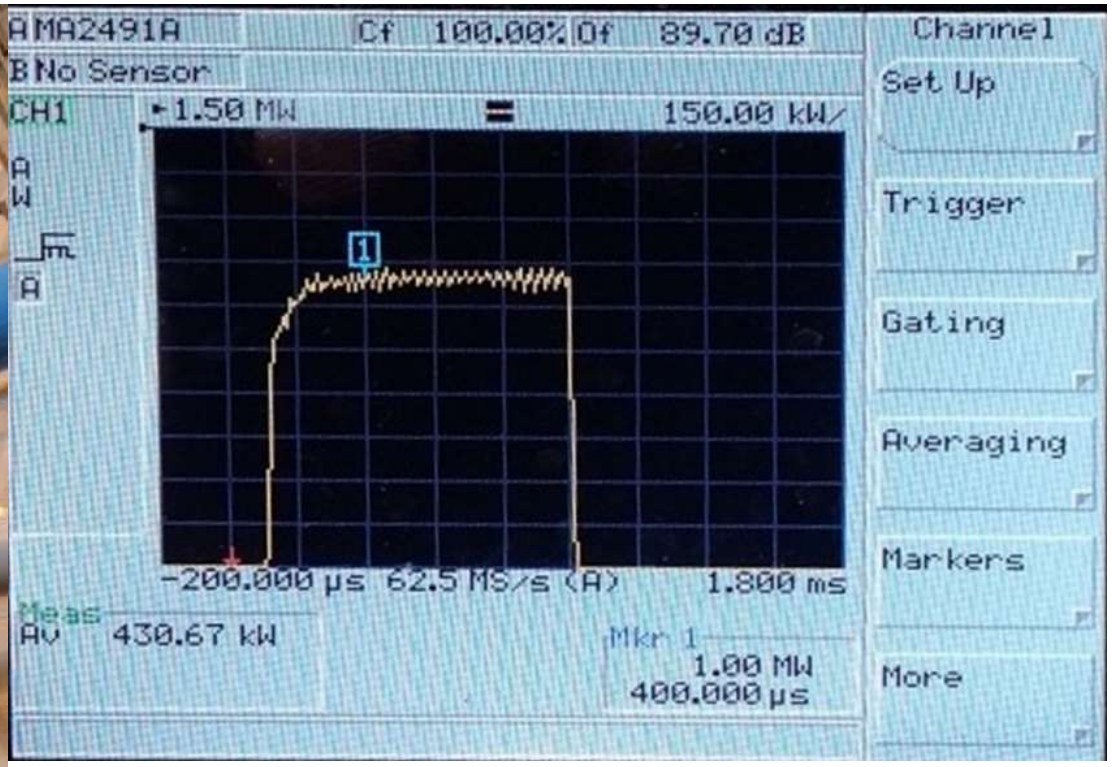
- RF Funding halted summer ‘16
  - Limited opportunities to advance this year
  - Some work completed before ‘halt’ order, others work as risk mitigation
- Distribution network
  - Components assembled into distribution network at DL
  - Components delivered to RAL from DL for installation
  - Adapted from components procured under NSF-MRI for earlier configuration
- Status of RF drive system
  - Triode No. 2 under test, started mid March
    - Exploiting 1st tetrode, and upgraded No. 1 modulator racks
    - Triode achieved 1MW using ex-ISIS valve (close to limit of valve)
    - Modulator/RF glitches noted when tetrode > 50kW into triode
    - These are now understood
  - Interface channels for RF controls defined
    - Work underway to complete control crates (DL subcontracted work)
  - LLRF system demonstrated on ISIS debuncher (at low power)

# RF Distribution Network

- Must Support 2MW in 6” line and 500 kW in 4” line with full reflect
  - 4” lines rated to 1.12MW at 1 atmosphere in dry air
  - Therefore will be pressurised by $N_2$ (with slow ramp) or $SF_6$ or gas
    - Will be treated as pressure vessels
  - Some of the 6” and 4” line from the NSF MRI procurement modified
  - All components/devices will be drawn from the NSF procured stock
  - Calibration components procured
  - Distribution network components now at RAL



# RF Drive Systems




- 1st Modulator set and Tetrode recommissioned at Daresbury
- 2nd Triode is under test
  - 1MW achieved using ex ISIS triode valve at 25kV
  - η: 57%, Gain: 8.6 dB, Tetrode: 136kW, η: 52%, Gain: 19 dB
  - Triode input return loss 11.5 d**B**
  - At MICE duty and pulse duration

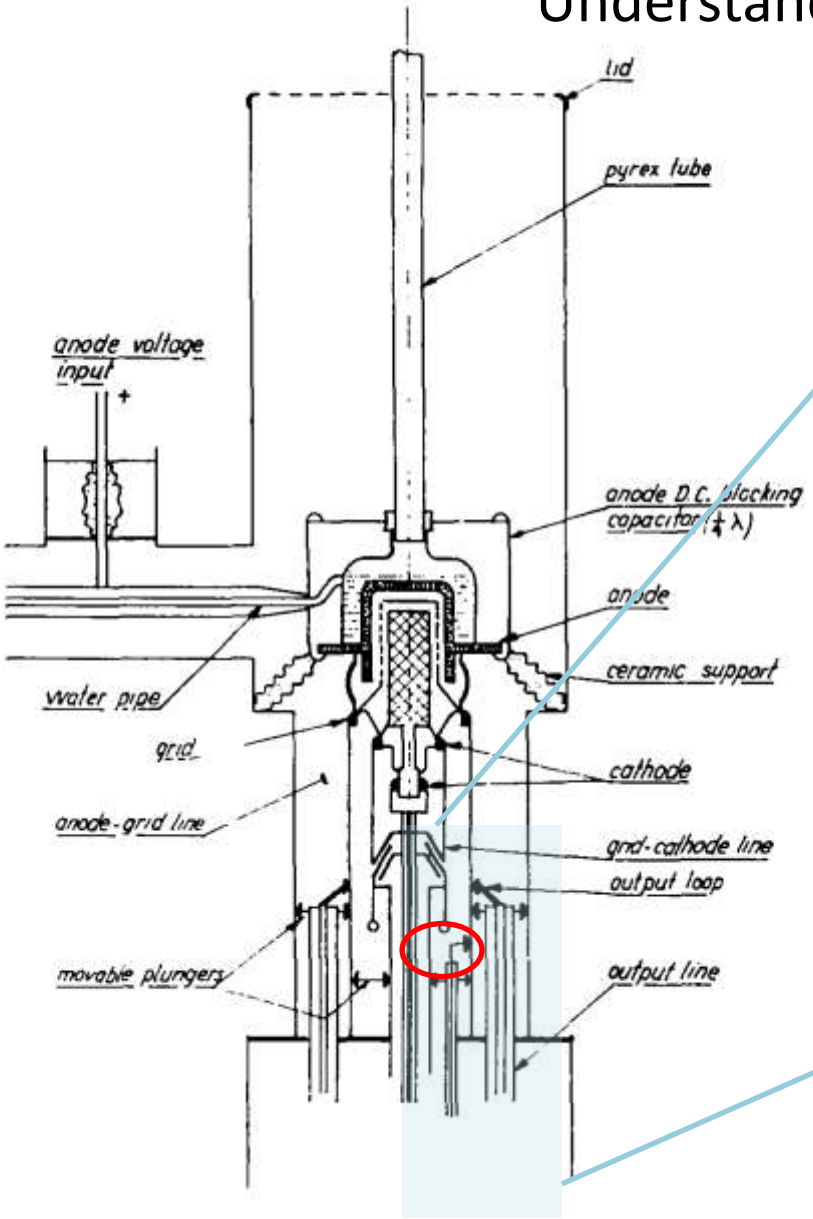
# RF Drive System

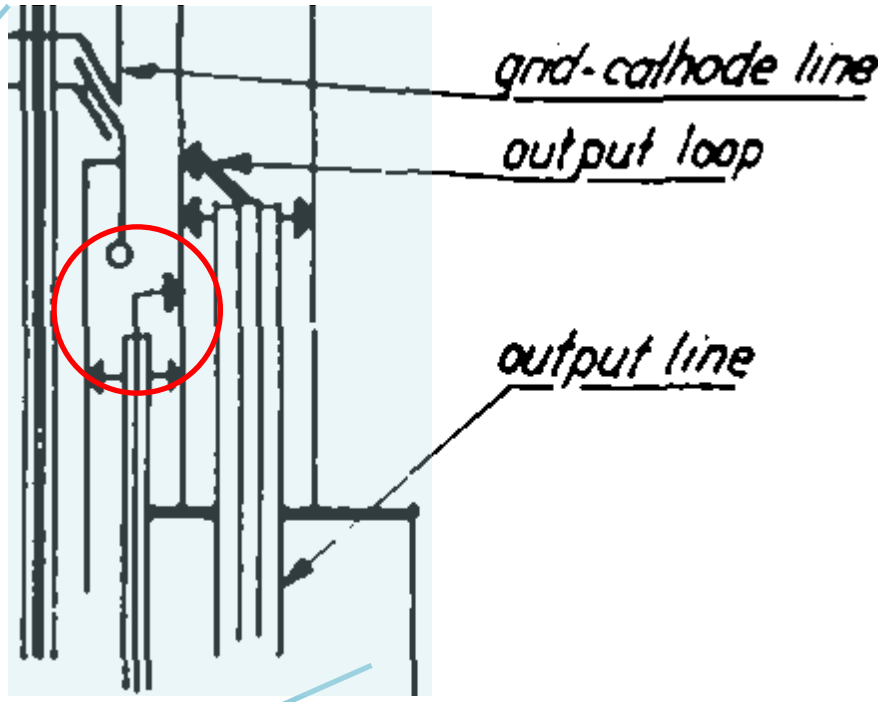

- Glitches observed in modulator current traces when Tetrode operated above 50 kW output
- Completely independent of RF output tuning of tetrode, triode, bias voltages on triode
- Maps to modulation of output signal of both triode and tetrode
- Does not happen when tetrode drives resistive load at MUCH higher power

# Understanding the Glitches

- Possible causes of the glitches considered
  - Capacitor charger 'noise' annoying the HT electronics
    - Problem got worse if charger switched off and system run in capacitor run-down mode- so not that
  - Unlucky line resonance – stored energy in tetrode output line modulating the tetrode anode swing-
    - Looked like the tetrode output spiked up then dipped at a glitch
    - But should improve with increased tetrode anode bias and eliminated with output coupler tuning- but no effect seen
  - New solid state crowbar 'twitching' triode HT circuit
    - Hard to see how this would not result in a full crowbar event
  - Sparking in the triode input
    - Surprisingly regular process for sparking
- Further tests
  - Eventually the glitches stopped, but the input match to the triode became very poor at all power levels
  - This implies a spark was the cause. Prize to Andy Moss for suspecting this.

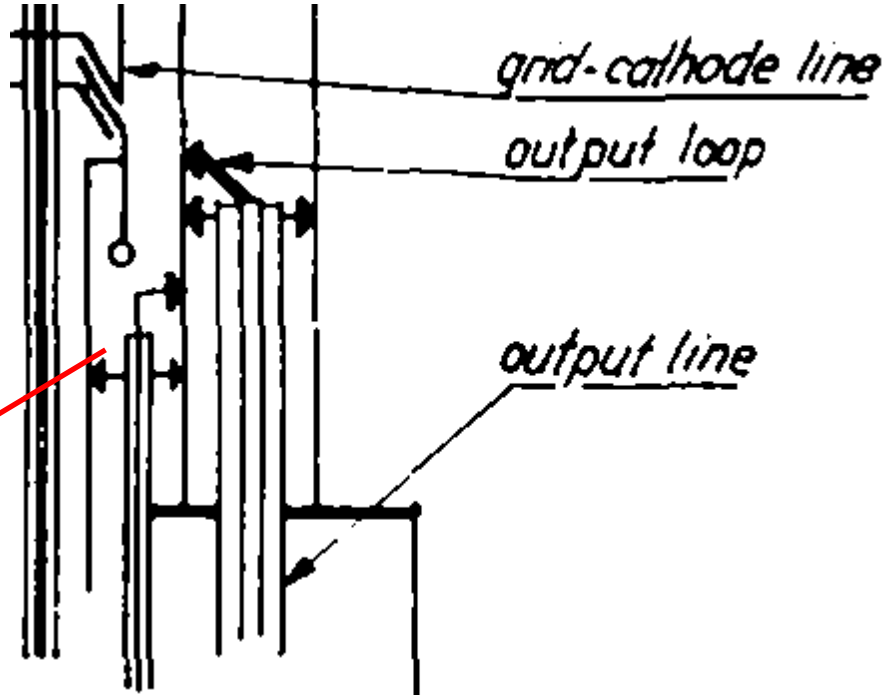
# Understanding the Glitches




- Suspect location
  - Matching Resistors in input line
  - Drawing from *E Zaccheroni et al, NIM, **5**, 78-89*

# Understanding the Glitches




- Suspect location
  - Only accessible by fully stripping the amplifier
  - This triode is only needed to shake down controls,
  - Scheduling considerations suggest we NOT do this
  - Drawing from *E Zaccheroni et al, NIM, **5**, 78-89*

# RF Controls and Monitoring Systems

- Channel list and State Machine Defined for RF amplifier controls
  - Enable the build of the controls hardware at Daresbury- Underway by Daresbury Electrical Engineering
  - Also defines the logical interaction with the system states
  - Software development commenced: associating channels with variables for EPICS control

- Daresbury TD have made major progress in building controls rack
  - In present FY funds available to complete Controls Rack
  - Commitments at DL mean that this is being undertaken by subcontractors
  - Programming of the software will remain to be done

# LLRF

- LLRF development has continued due to ISIS interest
  - Has been controlling tuners on ISIS debuncher cavity based on feedback signals
  - Low power tests only so far: Bob Anderson @ ISIS Injector RF Group

# RF Team and Equipment Status

- RF development continued  only as risk mitigation
  - Has had very limited amount of effort available on MICE RF
  - Tim Stanley (formerly MICE RF Engineer) now with ISIS RF
  - Limited effort available at Daresbury
  - Slowed progress where the project plan would have liked to increase effort

- Looking forward: if Cooling Demo Approved
  - Daresbury RF and TD groups heavily committed to CLARA
  - One key contributor may retire soon
    - We will need to make sure we can secure adequate RF resources
    - There may be a steep learning curve
  - We have a lot of (valuable) spare parts
  - We have most major capital equipment required
    - Limited procurement, clock and LLRF reference source hardware
    - Also cavity support infrastructure

# Work Needed for Cooling Demo

- Distribution network
  - Installation, calibration
  - Gas insulation scheme needs to be built
  - Adjustment of relative phase
- RF drive system
  - Resolution of the glitches issue on the test stand at Daresbury on Triode No 2
  - Completion of controls system- do we need such a 'hands off' system?
    - Tests of controls system
  - Installation in Hall and commissioning- provision of cooling water and controls cabling
  - LLRF system modified for MICE
- Cavities
  - Provision of auxiliary systems for cavities (cooling/air/vacuum)
  - Installation, integration with controls/monitoring/LLRF
  - Online commissioning
- Funding bid to access STFC underspend in FY 17-18
  - News due soon: Could fund completion of RF drive system
  - Would need prompt action to resource if successful