MICE RF System

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ASTeC

Collaboration meeting CM30

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  - Next steps
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  - Amplifier to cavity components
  - CAD modelling
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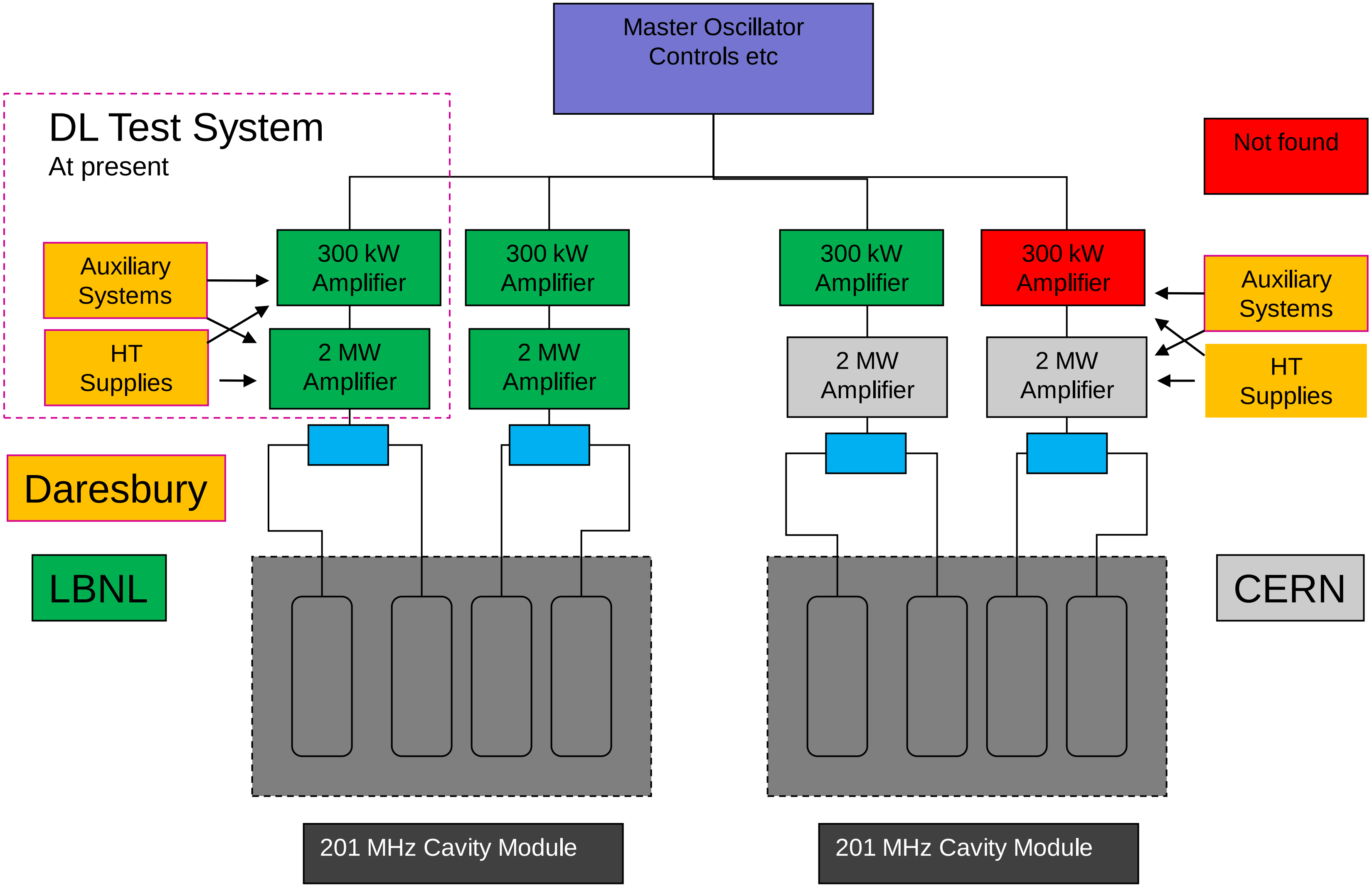
RF system components



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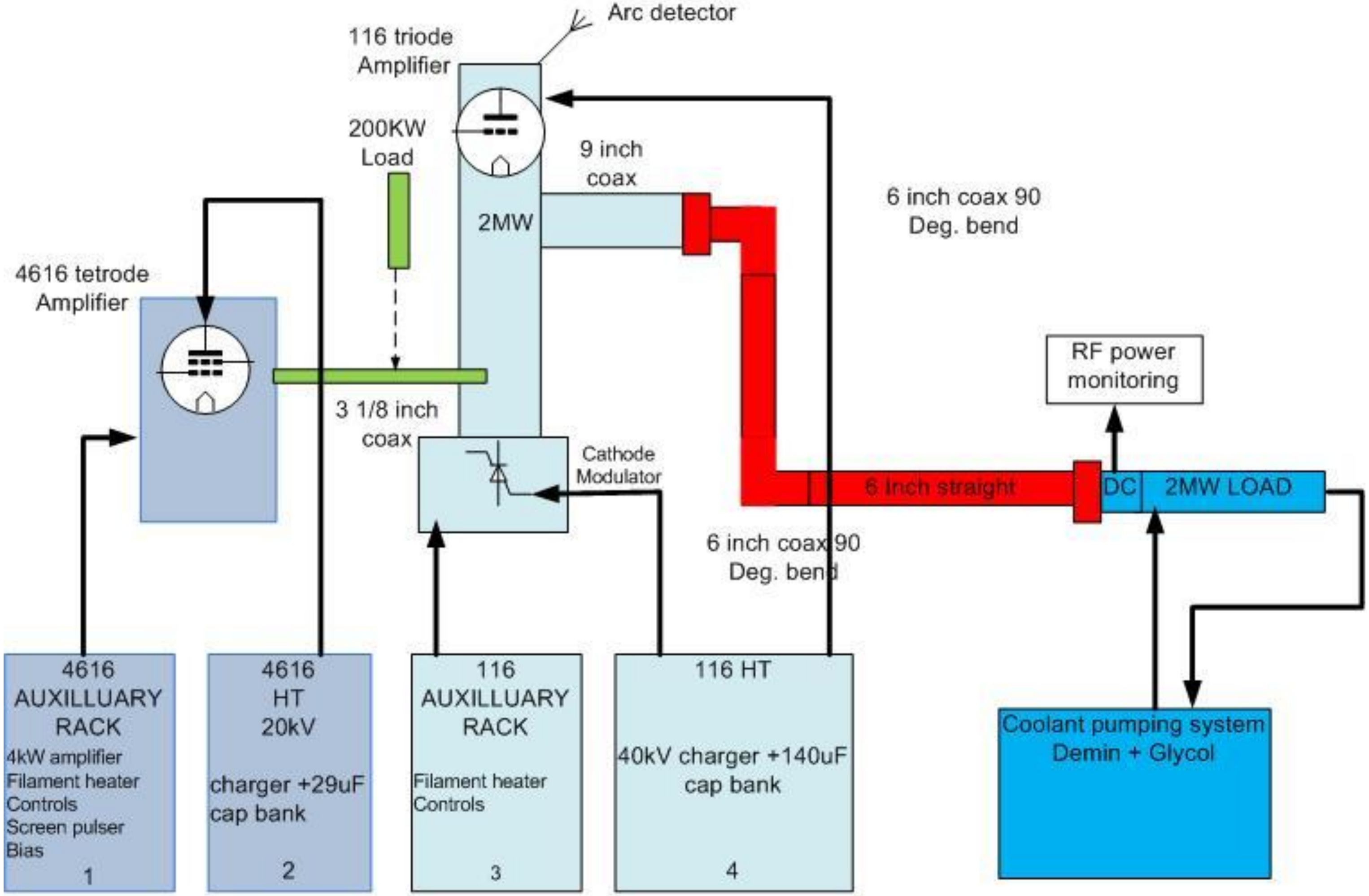
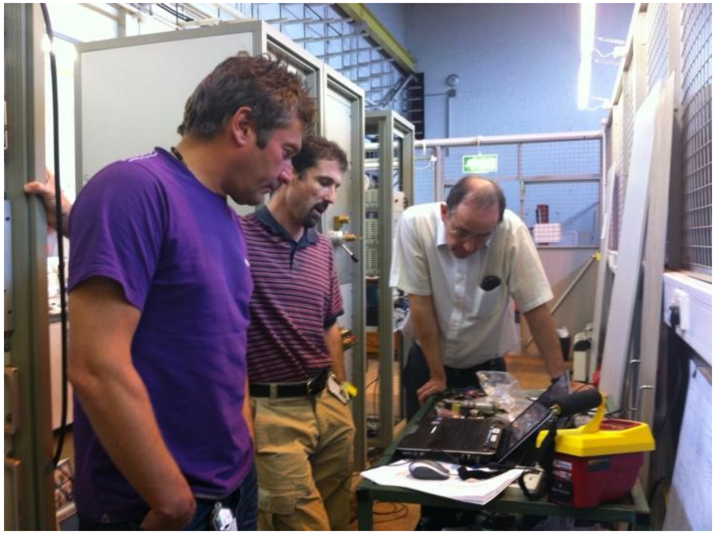
Test system at Daresbury



Daresbury test setup for proving amplifiers/power supplies

Initial testing

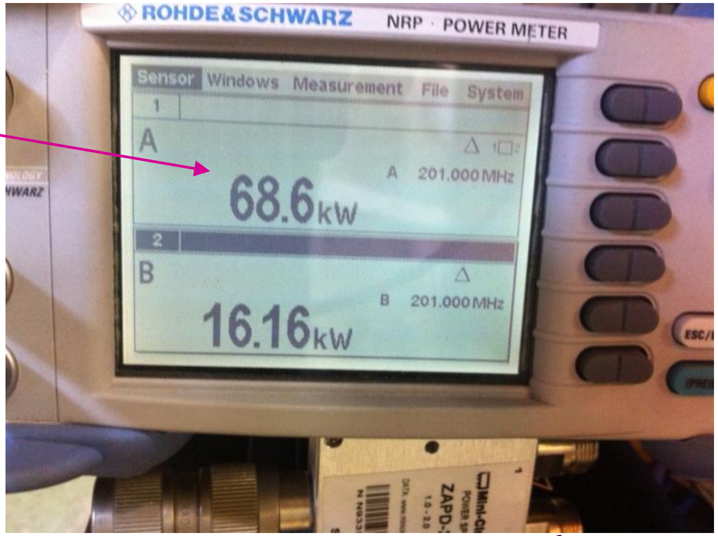
- 4616 connected directly into test load and set up to known 50 Ohm, then connected to input of main 116 amplifier
- When running into 116 high reflected power issues immediately, looked to be reflecting 50 % of power
- However match of 116 input changes with heating, RF drive level, HT applied and cathode modulator switching on, after playing with the system tuning match got much better (20% reflected power)



4616

forward

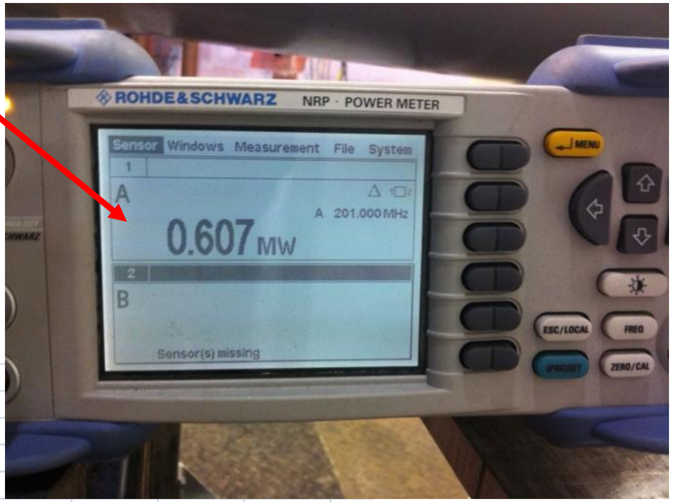
reflected



RF and power supply testing June

- System pushed to 600kW

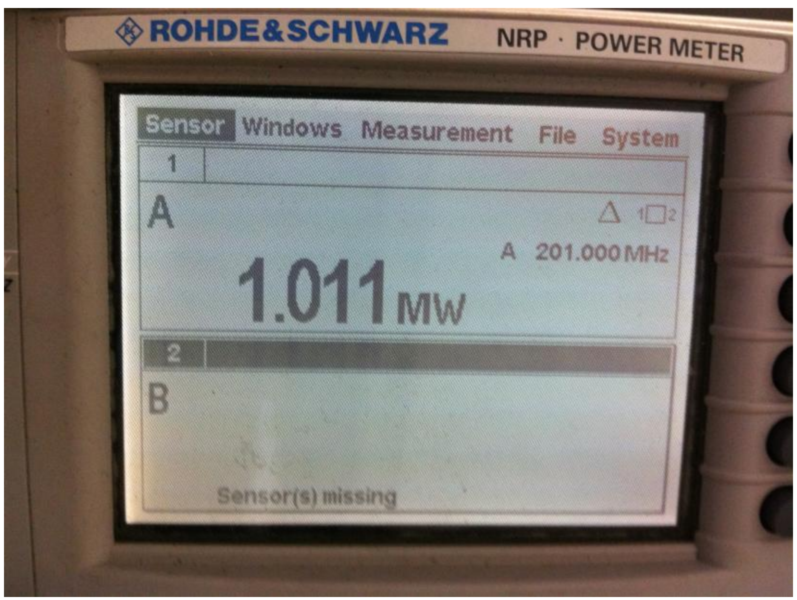
116 Forward power into load



Drive (dBm)	HT (kV)	Forward power (kW)	Reflected power (kW)	Reflected Power Percentage (%)	HT (kV)	Forward power (kW)	Reflected power (kW)	Beam current (A)	Electric power in tube (kW)	Efficiency (%)	Gain (dB)	
-3.8	15	10	2	20.0	10	87.3		21	210	41.6	9.4	
	15	10	1.7	17.0	15	127.5		25	375	34.0	11.1	
-1.8	15	14.27	2.59	18.1	15	166		28	420	39.5	10.7	
-0.8	15	17.6	3.29	18.7	15	191.1		30	450	42.5	10.4	
0.2	15	21.1	3.69	17.5	15	211		32	480	44.0	10.0	
1.2	15	27	4.74	17.6	15	250		35	525	47.6	9.7	
2.2	15	37	6.47	17.5	15	298		42	630	47.3	9.1	
2.2	15	37.3	6.51	17.5	16	330		43	688	48.0	9.5	
3.2	15	51.4	9.68	18.8	16	370		48	768	48.2	8.6	
3.2	15	53.6	12.45	23.2	16	376		48	768	49.0	8.5	6dB pad added on refl pwr
4.2	15	63.3	16.54	26.1	16	385		51	816	47.2	7.8	
3.2	15	54.6	12.7	23.3	16	379		48	768	49.3	8.4	
3.2	15	53.5	12.04	22.5	17	416		50	850	48.9	8.9	
4.2	15	65.6	17.95	27.4	17	439		52.8	897.6	48.9	8.3	Additional 3dB pad added
4.2	15	67.5	18.8	27.9	18	485		54	972	49.9	8.6	
4.2	15	61.3	14	22.8	18	474		53	954	49.7	8.9	Grid tap adjusted up to improve input match
4.2	15	56.6	11.4	20.1	18	464		52	936	49.6	9.1	Grid tap adjusted up again
4.2	15	55.6	11.53	20.7	19	499		53	1007	49.6	9.5	
4.4	15	59.6	12.65	21.2	19	508		54	1026	49.5	9.3	
4.4	15	59	12.27	20.8	20	539		54	1080	49.9	9.6	
4.4	15	58	11.9	20.5	21	574		55.5	1165.5	49.2	10.0	X-ray levels - background
5	15	65.8	14.37	21.8	21	599		57.5	1207.5	49.6	9.6	
5.2	15	68	15.51	22.8	21	606		58.5	1228.5	49.3	9.5	

RF and power supply last week !

- 116 amplifier produces 1MW !
  - No trips, arcs, x-rays or microwave leakage at this power level



Drive, efficiency, gain

Drive (dBm)	HT (kV)	Forward power (kW)	Reflected power (kW)	Reflected Power Percentage (%)	HT (kV)	Forward power (kW)	Reflected power (kW)	Beam current (A)	Electric power in	Efficiency (%)	Gain (dB)	
-0.2	15	17.06	3.16	18.5	15	120		30	450	26.7	8.5	
-0.2	15	16.73	3.1	18.5	15	184		31	465	39.6	10.4	
1.2	15	22.7	4.16	18.3	15	226		35	525	43.0	10.0	
2.2	15	29.1	5.33	18.3	15	264		38.5	577.5	45.7	9.6	
3.2	15	38.5	7.02	18.2	15	305		43	645	47.3	9.0	
3.2	15	39.8	7.14	17.9	16	340		45	720	47.2	9.3	
4.2	15	50.9	9.51	18.7	16	377		49	784	48.1	8.7	
4.2	15	51.9	9.61	18.5	17	417		50.4	856.8	48.7	9.0	
4.2	15	53.1	9.73	18.3	18	456		51.6	928.8	49.1	9.3	
4.7	15	58.4	11.4	19.5	18	474		53.6	964.8	49.1	9.1	
4.7	15	59.3	11.54	19.5	19	511		54.8	1041.2	49.1	9.4	
4.7	15	60.3	11.8	19.6	20	550		56	1120	49.1	9.6	
4.7	15	60.8	11.8	19.4	21	592		57.2	1201.2	49.3	9.9	
4.7	15	61	11.57	19.0	22	626		58.4	1284.8	48.7	10.1	
4.7	15	61.2	11.47	18.7	23	663		59.6	1370.8	48.4	10.3	checked x rays and RF. No x rays - 0.08mW
5.2	15	67.3	13.77	20.5	23	688		60.8	1398.4	49.2	10.1	adjust grid tap, 4616 forward and reflected both went up, took it back dwon
5.2	15	68.5	14.13	20.6	24	732		62.4	1497.6	48.9	10.3	
5.2	15	69.1	14.16	20.5	25	769		63.6	1590	48.4	10.5	
6	15	76	17.7	23.3	25	792		64.4	1610	49.2	10.2	Tried to adjust grid all values either up or down with change in position
6	15	75.7	17.08	22.6	26	827		66	1716	48.2	10.4	
6	15	75.7	16.9	22.3	27	867		67	1809	47.9	10.6	
6	15	75.8	16.45	21.7	28	902		68.4	1915.2	47.1	10.8	Background radiation , no RF leakage
6	15	75.8	16.45	21.7	29	939		69.2	2006.8	46.8	10.9	
6	15	75.8	16.24	21.4	30	975		70.4	2112	46.2	11.1	
6	15	75.7	16	21.1	31	1011		71.2	2207.2	45.8	11.3	
4.7	15	57.2	14.58	25.5	19	481		53.6	1018.4	47.2	9.2	
4.7	15	56.9	14.29	25.1	19	489		53.6	1018.4	48.0	9.3	
4.7	15	58.6	14	23.9	19	396		60	1140	34.7	8.3	moved 116 output tap in, output power down to 399
4.7	15	59.2	14.97	25.3	19	485		52.8	1003.2	48.3	9.1	moved 116 output tap out (past starting point), output power increasing
4.7	15	61	16.55	27.1	19	358		46.4	881.6	40.6	7.7	moved 116 output tap out further, output power decreaing
4.7	15	60.4	15.2	25.2	19	500		55.6	1056.4	47.3	9.2	moved 116 output tap back to start
4.7	15	61.1	15.3	25.0	19	506		54.8	1041.2	48.6	9.2	moved anode tap both ways, but we were in optimum posistion

Consistent results from all measurements – system is performing correctly

Adjusting all taps to see effect on parameters

Further 116 testing

- Old ISIS 116 tube showing gain of 10 which is to be expected, should be useful up to 1.2 MW?
- Will test again and push current old 4616 & 116 to the point were gain drops off, indicating the limit of the tubes.
- Switch 4616 & 116 to new MICE tubes and push to 2MW
- So far the amplifier system seams very well behaved at up to 31kV and 1MW, however a long way to go yet ! Quietly confident ….

Coax design

- Hybrid power splitters to divide power before each cavity with a rejection load, this should provide a robust reliable system
- Local phase shifters in each coax to adjust cavity coupler and for change in energy, small range available only, so need to plan coax system carefully to get phase lengths within range at the cavity input couplers
- From 140 – 240MeV/C phase of cavities will alter by 16 degrees, LLRF drive and coax phase shifters used to enable this
- Power monitoring in each section of coax will be linked in to RF control system so that issues can be flagged before faults occur
- Nitrogen gas pressure system with the coax for voltage stand off and interlock, SF6 will be needed to operate cavities above 1MW
- Plan to have the ability to connect test loads in place of cavity to test amplifier/coax system in its complete configuration

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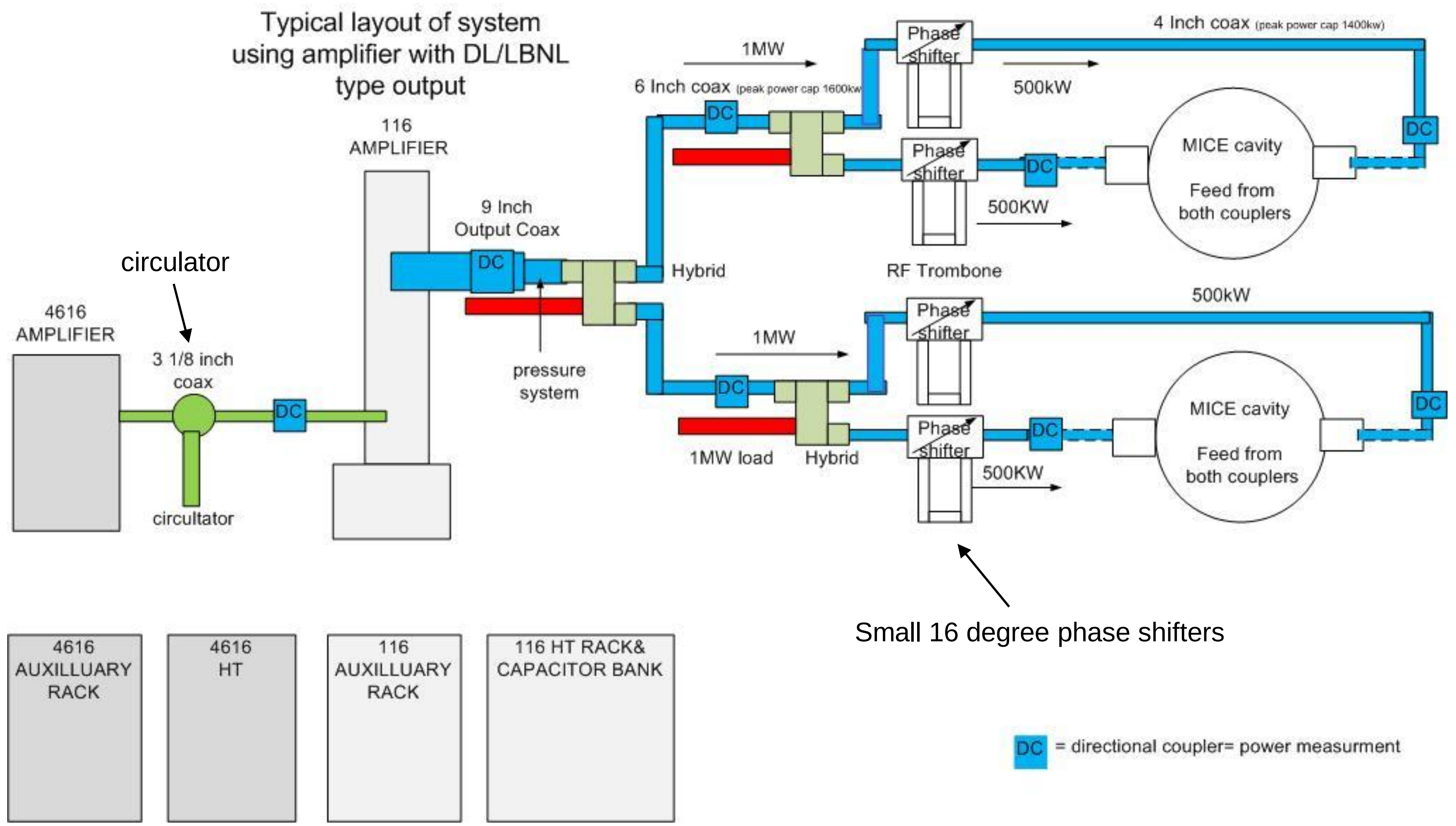
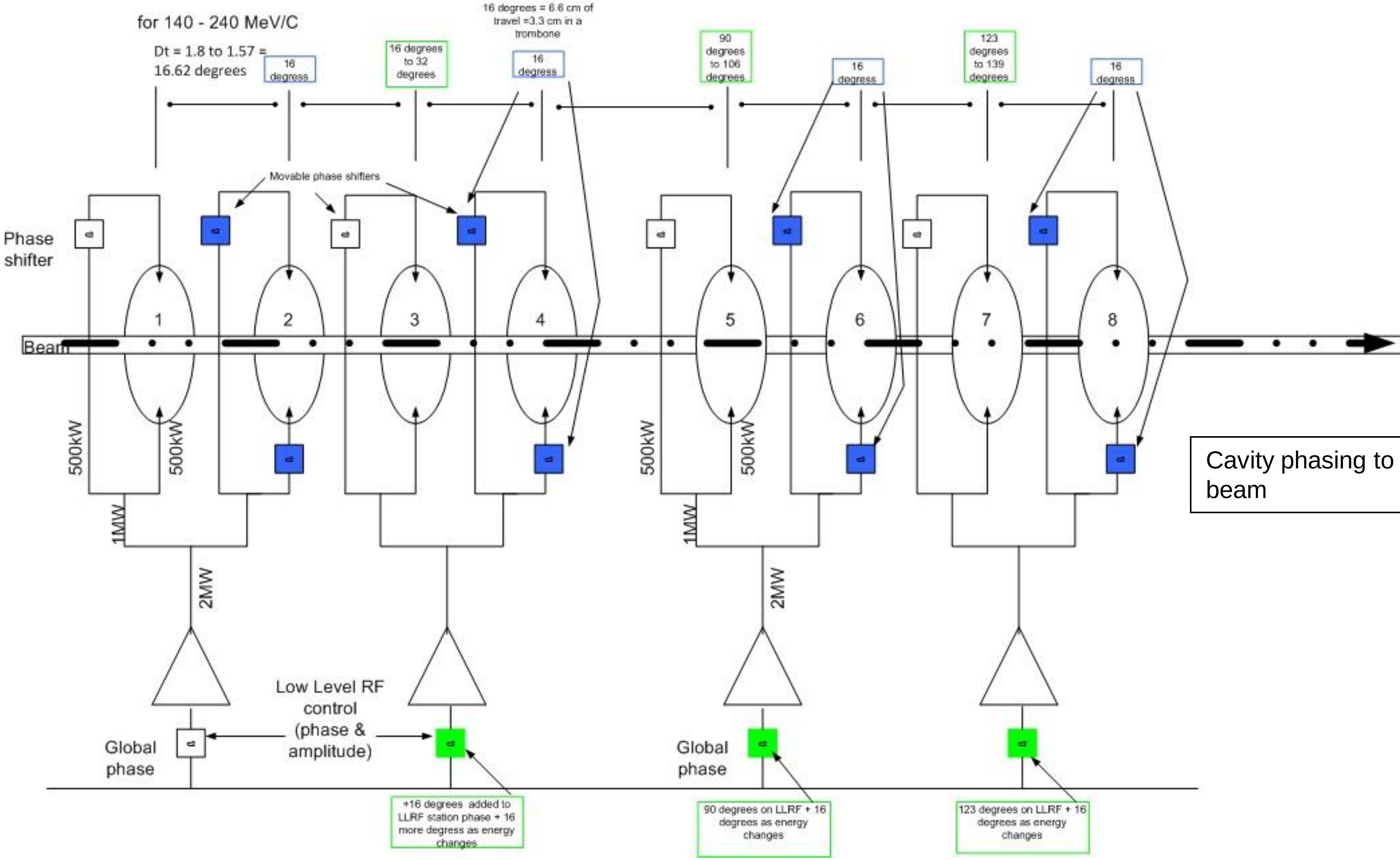
Predicted hall layout for RF components

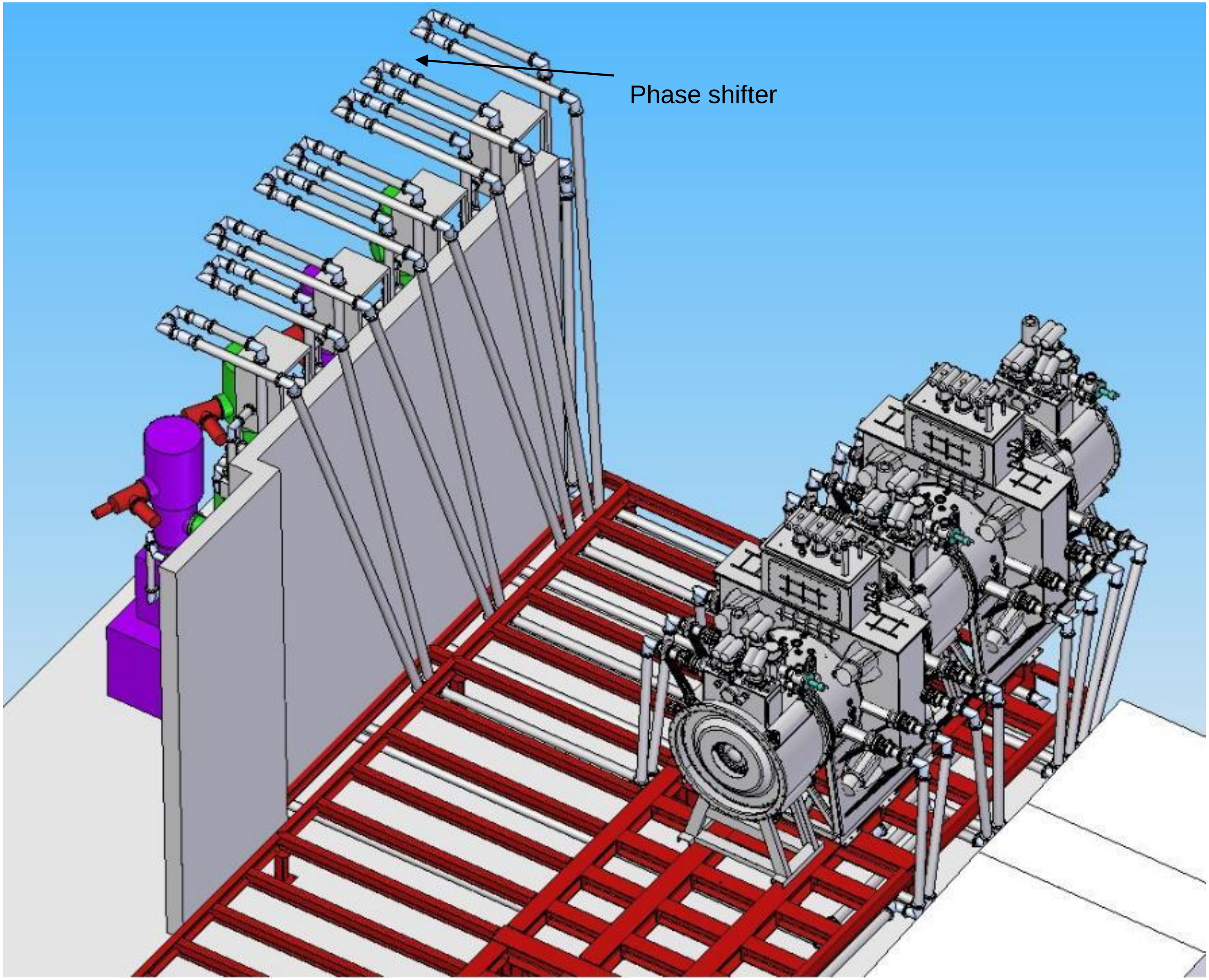


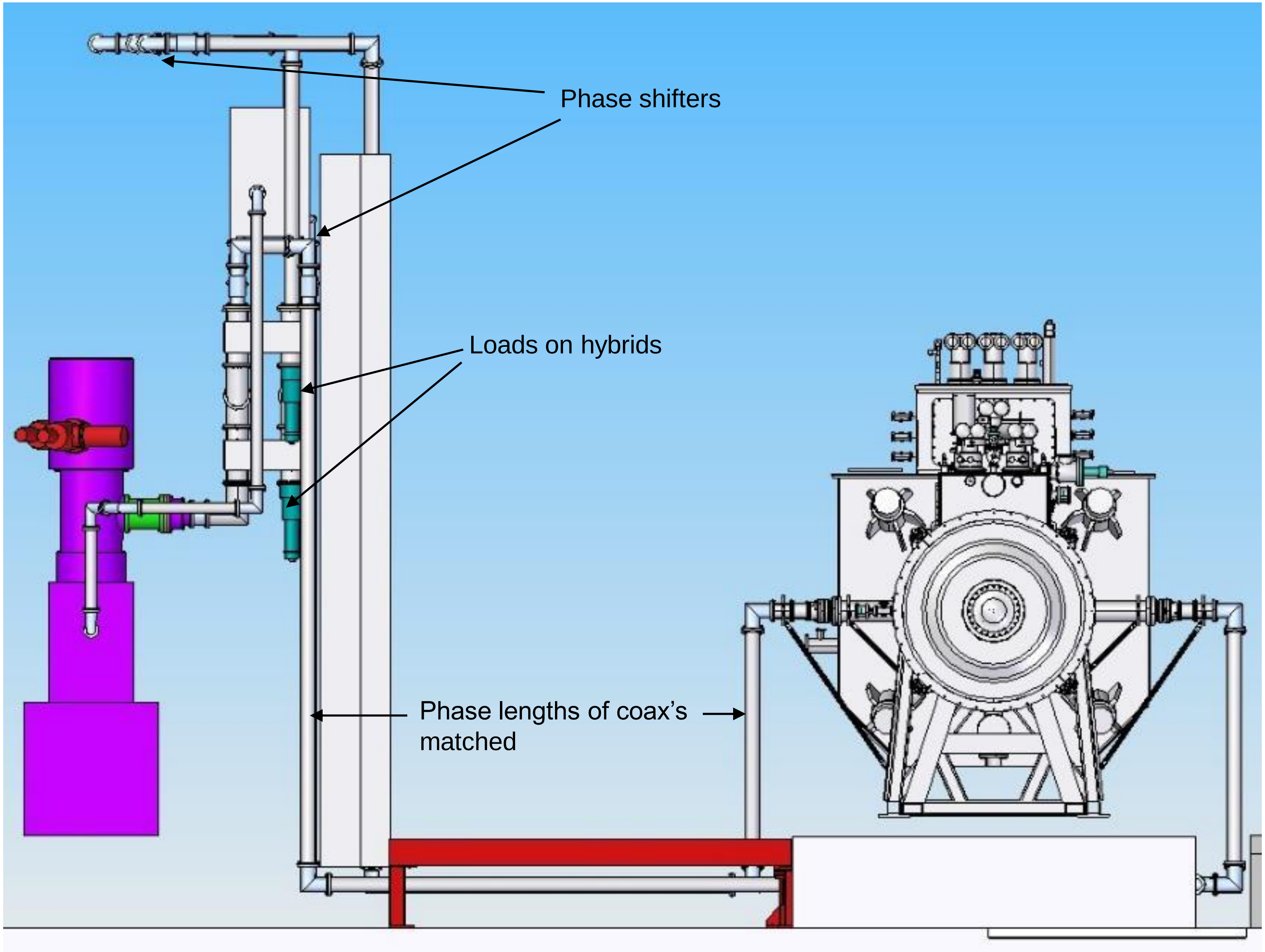


Cavity phasing to beam

Layout optimisation

- Try to get as much of the complex RF devices out from under the floor so that floor does not need to be lifted if there is a problem
- Still need space around amplifiers to work on them, smaller loads will help here, now shown on layouts
- Small trombone phase shifters behind shield wall freed up a lot of space, will be motorised
- move feeds to cavity couplers as close as possible to under the required port


Phase shifter

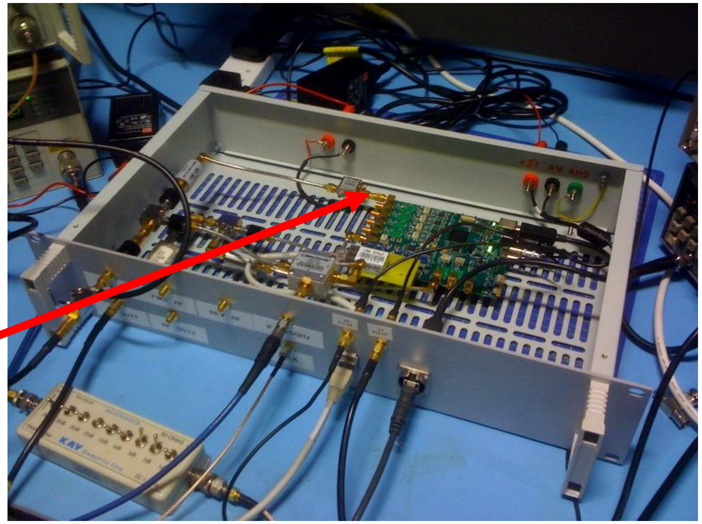

Phase shifters
Loads on hybrids
Phase lengths of coax's matched

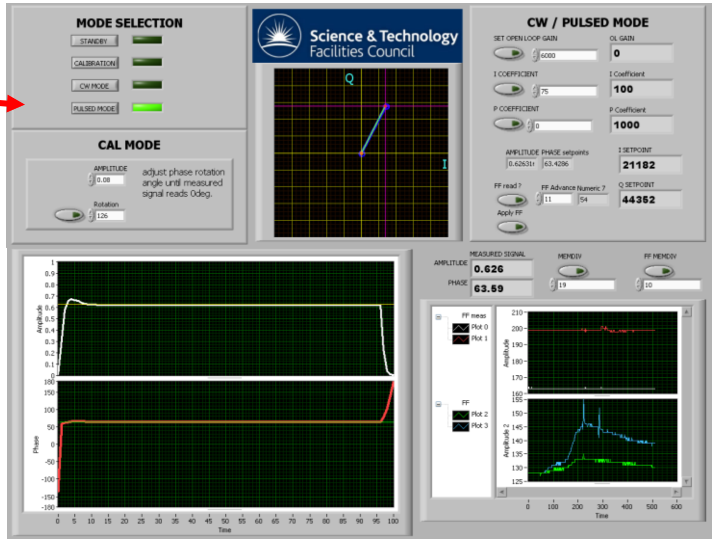
Layout further work

- Current CAD models of coax will have a design review
- Write specification based on design review results for coax system to be purchased
- Entire coax system should be competitively tendered for – MRI funds in USA

Low Level RF control

- At Daresbury low level rf (LLRF) system has been developed to stabilise cavity amplitude and phase to better than 0.5 %
  - Tested on copper and superconducting cavities
- The LLRF4 board (developed by Larry Doolittle at LBNL) is used as the basis for the design.
- Front end program is a state machine connected to an EPICS server
- Amplifier system forward and reflected power signals could be monitored through a National Instruments DAQ system, easy to program for alarms
- EPICS compatible





Controls

- RF powers supplies use Siemens S7 PLC’s for control – compatible with EPICS
- State machine approach is used as a baseline for all systems at DL
  - No formal high level design of controls for RF done yet, however we understand the global approach to control system for MICE

Conclusion

- 116 amplifier has produced 1MW using old tubes, very stable and conclusive results from all measurements – see no big issues to get to 2MW now
- Amplifier to cavity components are understood, however may need to make compromises for the real world
- Coax design is complete, but will take advice from review and amend – ready to procure
- Options for LLRF control