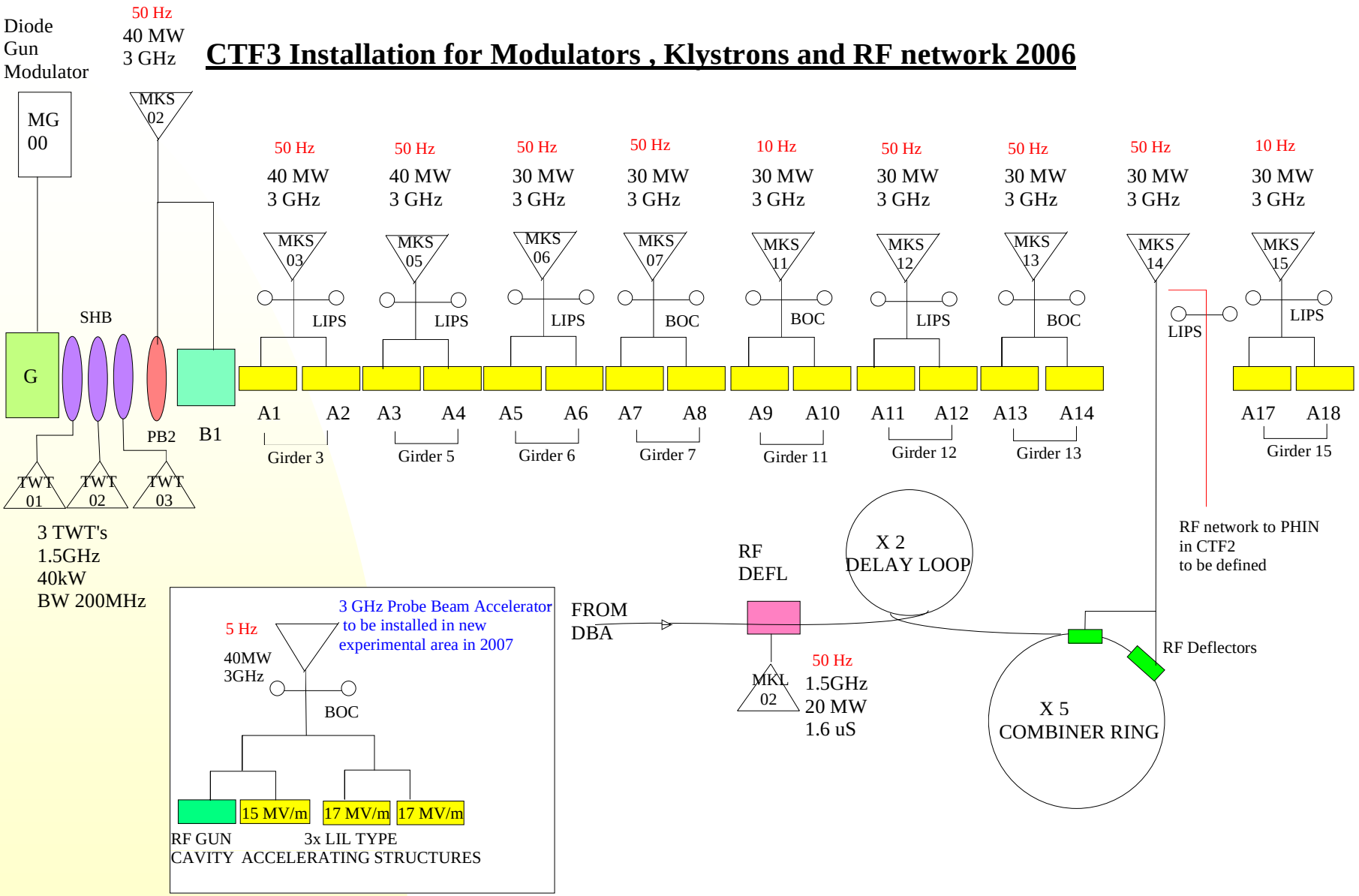
RF System including Stand-Alone X-Band Source

G.McMonagle AB/RF

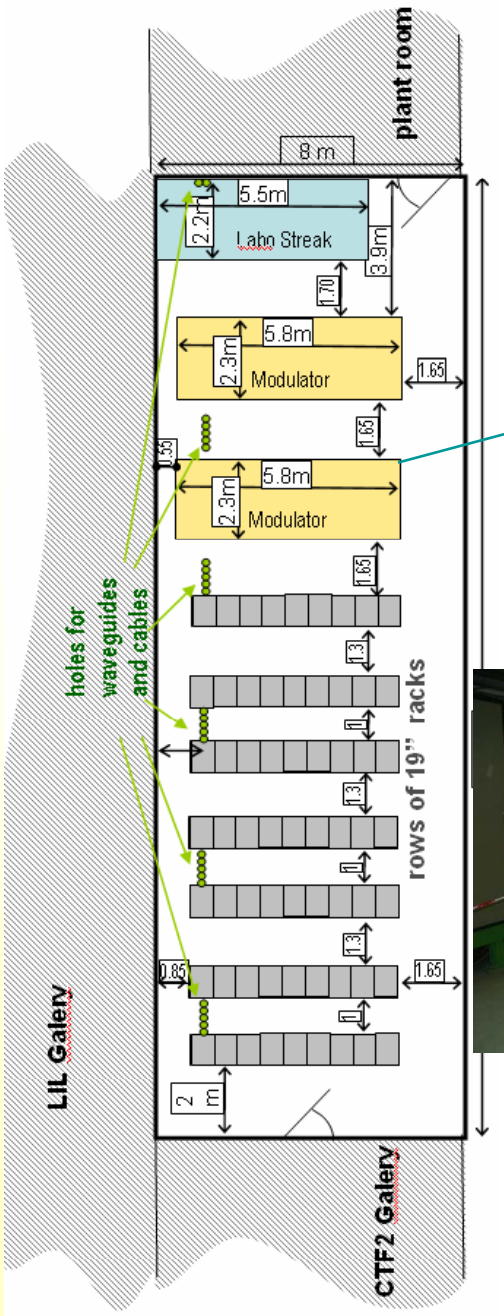
Introduction

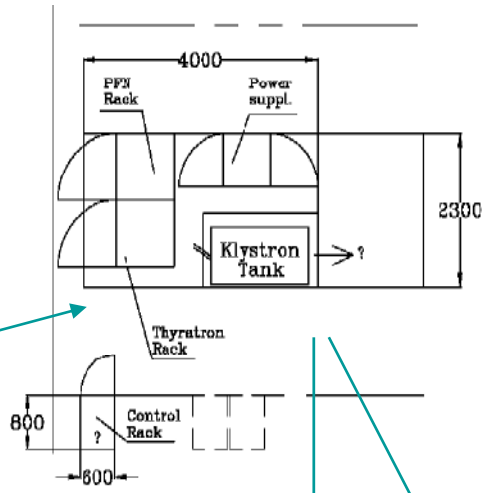
- Overview of existing installation
- Progress on probe beam RF installation
  - Modulator
  - RF network
- RF network for PHIN testing
- Observations on 2007 operations
  - Modulators
  - Klystron situation
  - TWT's
- Improvements foreseen in 2008
- 12 GHz stand alone power source project

CTF3 Installation for Modulators , Klystrons and RF network 2006



CALIFES MODULATOR





Modulator installed in gallery in November 2007

Provisional acceptance completed before shutdown

Achieved nominal voltage on 37MW klystron

Some PN adjustments to be completed for overshoot and ripple

Noise problems ?

New klystron and focal set to arrive by March 2008

Final commissioning of modulator foreseen March/April 2008

RF network for Probe Beam

- Waveguide bends ordered in October after price enquiry
  - The supplier (who we have had previous experience with in machining and brazing of waveguides) was unable to provide acceptable prototypes

Attempts at bending copper waveguides

RF network for Probe Beam

- Order in process of being cancelled and negotiation of payment for partial completion of work (treatment and plating of flanges)
- New order being generated with a company in Paris who have already produced waveguide bends for CERN
- BUT DELIVERY TIME 18 WEEKS (early June)
- Waveguide straight pieces have been machined order being generated for brazing delivery foreseen in March
- Variable attenuator ordered, delivery foreseen end April 2008
- High power vacuum phasor under construction with CEA
- Small waveguide lengths to be manufactured once RF gun arrives at CERN. Phase measurements to be made to calculate lengths required

RF network for PHIN

- 60 metres waveguide from MKS 14 installed
- Area in building 2013 above CTF2 being prepared for installation of LIPS will be ready mid to end February 2008
- Once PHIN gun arrives phase measurement to be made and waveguides for phase adjustment to be manufactured
- Can use MKS14 for PHIN testing from start up of 30 GHz testing in April (if the gun arrives in time) This can continue until the RF deflectors in delay loop are needed (few hours switch over necessary)

Observations on 2007 operations

- Modulators 02,03,05,06 and 07 ran for approximately 5500 hours (Heater) This was for 30 GHz production and full Linac operation
- Modulators 11,12,13,14,15 ran for approximately 4000 hours (heater) this was for full Linac operation
- Modulators and klystrons running at approximately 95-100% of their peak capability
- Spec 4.5µs RF pulse and 6.8µs HT (at 75% height)
- Actually running 5.5µs RF pulse and 7.8µs HT (at 75% height)… at reduced rep rate
  - No immediate redundancy if one modulator is down
  - Peak power, phase programming, timing etc must be adjusted on other modulators to compensate
  - This takes time, anything up to one day if starting from scratch
- Major component failures in modulators were the switch mode capacitor charging supplies in MKS11 and MKS 15. It seems to be a weak point on the HT output diode stack that if one fails a catastrophic chain reaction occurs killing all the HT circuits
  - this has happened before and power supplies were repaired in USA (long delay up to 6 months with shipping and bad after sales service)
  - No spares

Observations on 2007 operations

- End of line diode assemblies are known to fail if excessive arcing occurs in the klystrons (especially in the 45 MW modulators)
  - These assemblies failure rates have significantly increased since we have been running at full modulator capacity. This was not noticeable in LPI runs when modulators were running at 60% capacity
  - Difficult and expensive to acquire replacement diodes, capacitors and resistors
  - New diode stack has been installed in MKS02 to be tested at start-up, if successful replacements will be bought for other modulators
- Snubber capacitors on klystron heater circuit failed on several occasions
  - These capacitors are normally replaced every 2 to 3 years during annual preventative maintenance but recent failures seem to come from the last batch ordered. Manufacturer say no change in production or spec of capacitor
  - New capacitor manufacturer found, no failures on new type

Observations on 2007 operations

- 1 TWT failure
  - We have three operational TWT amplifiers each with a 40 kW TWT tube
  - 1 spare TWT tube that can be installed in the amplifier but has to be sent back to manufacturer for the TWT replacement
- Operated with 2 TWTA while faulty one was sent back to manufacturer for evaluation
  - Diagnosed as TWT up to air
  - Tube replaced (at a price) and sent back to tube manufacturer under guarantee
  - Tube manufacturer now say TWT was operating fine !
- Now have 3 TWTA's operating again and 1 TWT spare
- Operational problem with L band klystron for RF deflector. Not enough power to deflect bunches into delay loop.
  - Eventually found that there was a very small water leak in the high power water load on the circulator and water ended up on the ceramic of the RF windows at the deflecting cavity
  - Thales provided a spare load (thank you) while evaluating damage and doing eventual repair
  - Damage to o rings on load, deemed by Thales to have been caused by sudden overpressure on circuit

Observations on 2007 operations

- First full year of operating with new temperature control system for the pulse compressors that showed a significant improvement in the time to achieve a stable beam after a klystron fault or new output power setting
  - BUT NOT WITHOUT PROBLEMS
- Recall
  - During LEP runs we had 4 klystron modulators for LPI and 4 for CTF2. The CTF2 were considered spares for any failures in the LPI modulators, and CTF2 downtime was accepted as part of LPI operations
  - LPI klystrons were run at 60% of nominal power for approx 6000 hours per year and a 98% availability was achieved
  - 7 FTE equivalents in the MDK team to achieve this
- CTF3 has 10 S band and 1 L band klystron modulators running at 95-100% of nominal with larger pulse widths and 3 TWT's
  - No facility to test spares, conditioning needs to be done online i.e. longer downtime
  - Some components don't have spares, consolidation necessary
  - 4 FTE equivalents in MDK team

Klystron Position and Hours January 2008

MODULATOR	TANK		KLYSTRON	Peak Power	No. Of Hours				
	Number	TX ratio							
MKS02	13	14.8	TH2100 S.No.40	42 MW	6750				
MKS03	11	14.8	TH2132 S.No.21	45 MW	16770				
MKS05	2	14.8	TH2132 S.No.13	45 MW	21800				
MKS06	4	13	YK1600 S.No.12	35 MW	24630				
MKS07	1	13	YK1600 S.No.5R	35 MW	24600		HOT SPARES		
MKS11	6	13	TH2094 S.No.2R	35 MW	24230	Klystron	Peak Power	No. Hours	
MKS12	5	13	YK1600 S.No.6R	35 MW	5500	TH2132 S.No.22	45 MW	0	in tank 12
MKS13	10	13	TH2100 S.No.7	37 MW	6200	TH2100 S. No.10	37 MW	0	to be installed in tank 7
MKS14	3	13	YK1600 S.No.11	35 MW	29500	TH2100 S.No.11	35 MW	0	to be installed in tank 8,
MKS15	9	13	TH2100 S.No.8	37 MW	3300				high gain and diff perveance
MKL02		13	TH2170 S. No.1	25 MW	3700				
						SPARES			
						YK1600 S.No8	35MW	5000	RF breakdown on window
End of Life									
KLYSTRON	Peak Power	No. Of Hours							
TH2100 S.No.23	37 MW	28800	to be sent back for repair						
TH2132 S.No.17	45 MW	20500	to be sent back for repair						
TH2100 S.No.24	37 MW	10500	to be sent back for repair, filament failure (out of guarantee)						
TH2094 S. No. 9	35 MW		filament failure non repairable						
YK1600 S.No 4R	35 MW	43000	non repairable						

Klystron Situation

- Three klystron failures this year
- We now have three klystrons mounted in tanks, but are not “hot” spares as they are not conditioned, 2 TH2100 and 1 TH2132 (will try to condition them during initial start up while doing PETS operation)
- one Valvo tube in storage with a doubt on performance due to arcing on one of the output windows (need a Valvo tank and free modulator to test it)
- One TH2100 (45MW) on order for delivery in Feb/March for use in CALIFES modulator
- 2 maybe 3 Thales tubes to be sent back for evaluation and either repair or replacement

Consequences of future Valvo tube failures

- Should a Valvo tube fail it will need to be replaced by a Thales tube
- This means mechanical modification of the focussing magnet set before it can be used
- Two focal sets have been ordered from Thales,
  - one for CALIFES
  - one eventually for new spare HT tank or can be used to allow Valvo tank to be used in parallel to the focal set being modified
- If being replaced by 45 MW tube a new pulse transformer is needed as well

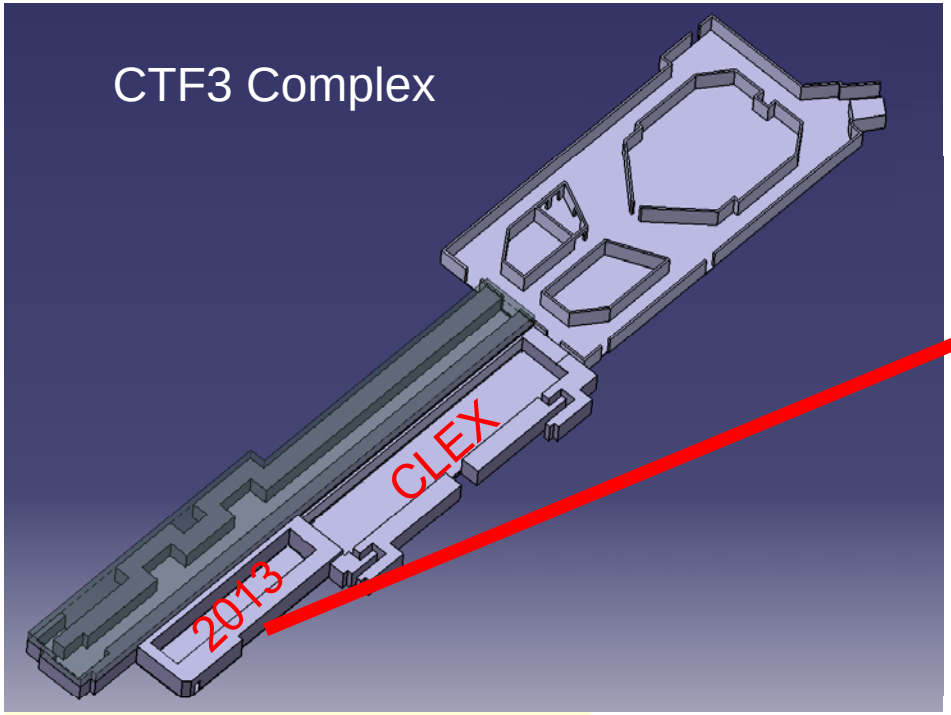
2008 RUN

- New charging supplies for MKS11 and MKS15 (European supplier) and a spare?
- New interlock system separating the complex into 4 zones will allow the modulators and klystrons to run without interruption while access into rings, CTF2 and CLEX
  - This will reduce klystron and thyratron fault rate
- Any new Thales TH2100 klystron will have a higher peak RF power output capability (from 37MW to 43/45 MW)
  - Modulators can provide the extra power, but new pulse transformer required in klystron tank to achieve required cathode voltage on klystron
- New snubber capacitors to be fitted on klystron heater circuit when necessary
- Will use period April/May, when only 30 GHz operation, as test period with other modulators to get klystron and thyratron “hot spares” conditioned to nominal
- Pressure release valve on water circuit of L band load

2008 RUN

- Suggest setting up machine with “missing” modulators and archiving settings. This would allow for quicker recovery of beam operation while modulator or klystron being repaired
- PSI MODULATOR
  - In 2007 PSI donated a major part of a LPI type modulator that will be installed in the CLEX building next to the CALIFES modulator
  - Still needs a significant financial and manpower contribution to get it operational
  - Would like it to be used for testing and conditioning spare parts, but will probably be used for the missing modulator to power girder 14

12 GHz Stand alone power source

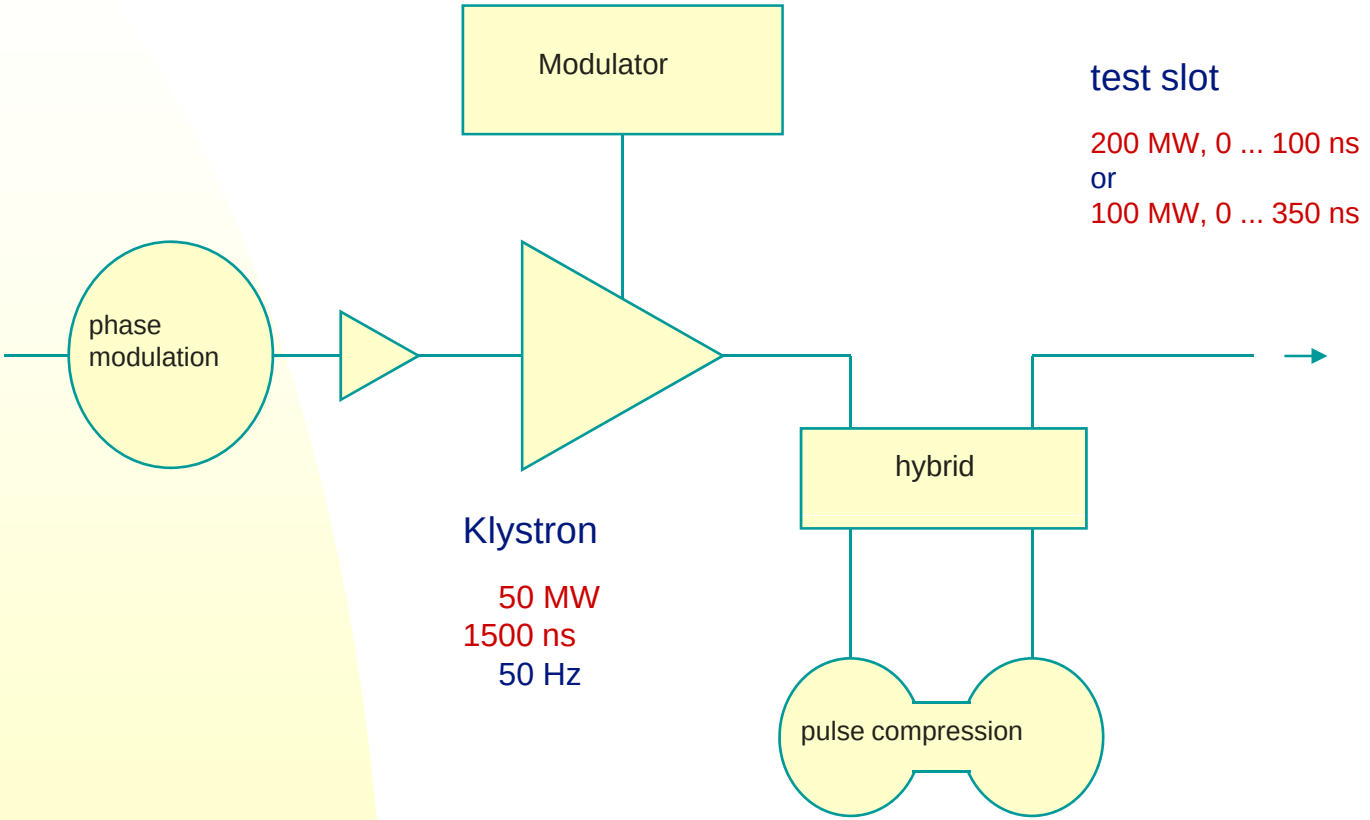


1st Floor B 2013

Old CTF2 Streak Camera area
Space available now
suitable for 1 klystron modulator

Installing the klystron modulator in 2013 allows for a stand alone test area below in the CTF2 area but also allows the possibility to eventually provide 12GHz RF power to the CLEX area if necessary

Test stand requirements



Klystron Modulator Parameters

Parameter	Value	Units
RF Frequency	11994.2	MHz
Peak RF power	≥ 50	MW
RF Pulse Width	1.5	µs
HV pulse width	Approx 3 to 3.5	µs
Repetition Rate	50	Hz
Peak Klystron Voltage	410	kV
Peal Klystron Current	310	A
HV flat top	1.5	µs

Collaboration with SLAC on klystron design approved by FC.
Klystron will be based on the XL4 11.4 GHz SLAC model
Modulator price enquiry in February 2008
Very tight and optimistic programme to deliver a 12 GHz RF power setup at CERN for mid 2009

Conclusions

- 2007 was a new learning curve for the MDK team to keep a large number of systems online while running them at full power
- Component weak points identified in modulators and consolidation necessary (including spare parts)
- Will be very difficult to keep downtime to a minimum while running at full power.
- Hopefully when klystron replacements are in place and all tubes are 45 MW type and girder 14 is powered, the modulators and klystrons can run at say 80% of nominal and this would increase the reliability
- Very successful ongoing collaboration with CEA Saclay for the CALIFES project
  - Thanks to all participants
- Challenging program in 2008
  - Consolidate and keep existing systems running,
  - commissioning CALIFES modulator
  - installation and commissioning of RF network for CALIFES
  - Testing of PHIN in CTF2
  - Completion of PSI modulator
  - -1 FTE in team due to retirement (thank you Guy for all your efforts over the years)
- 12 GHz test stand
  - Challenging and exiting program over the next 18 months
  - Need the technician post from the white paper allocation ASAP if this is going to be realised in the required timescale