

Figure 2: Layout of vacuum pumps

List of abbreviations

PPI	Power Pulse Incident
PPR	Power Pulse Reflected
PKI	Power Klystron Incident
PKR	Power Klystron Reflected
PSI	Power Section Incident
PSR	Power Section Reflected
PLI	Power LIPS Incident
PLR	Power LIPS Reflected
LIPS	LEP Injector Power Saver

All powers, unless specified otherwise, are measured on the PKI coupler during week 49 and on the PLI coupler during week 50 since only the second week the LIPS was used.

During the first week (49) 19.3 MW was obtained at the output of the klystron (PKI). This power was the maximum obtainable with 180 W at the input (this means the klystron was not saturated), a square input pulse (PPI), a limitation on the PFN of 33kV due to the age of the klystron, and no LIPS connected.

The second week (50) the LIPS was connected and the ramps of the input pulse were altered to obtain a smoother output pulse of the klystron in order to allow more RF power into the section. At the end of this week 23MW of RF power at the input of the waveguides was reached. The problems in achieving this value were due to the breakdowns in the LIPS (it hadn't been used for over 2 years) and in the last stadium it was also due to breakdowns in the HCS section. The RF formation had to be abandoned at the end of week 50 since the CTF was going to be opened for the shutdown of 97/98.

The following report will give an chronological overview of the events that took place those weeks. The increase in RF power are visualised in graphs.

Week 49 (RF formation done with a rectangular pulse and without LIPS)

Friday 28.11.97 (week 48)

The RF formation was started at 15:00 with 730kW on the PKI coupler. Using a PPI Pulse length of 2.3 μ s the first breakdowns were observed at 935kW. The MDK was switched OFF for the weekend just after 17:00. The graph is shown in figure 4.

Monday 01.12.97

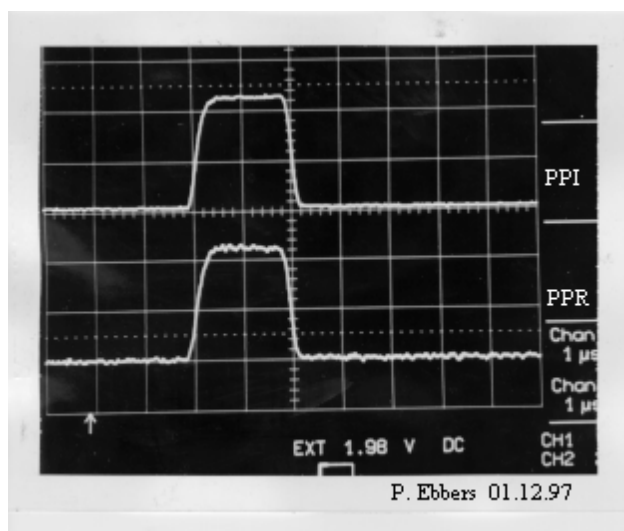
In the morning the MDK was switched to Stand-By but there was no RF formation possible since there is a CTF machine access. Afterwards Security tests were carried out on the MDK29 which affected our MDK 03 as well.

Finally at 14:00 the RF formation was started at 1.3 MW and 20kV on the PFN. It only lasted for half an hour and the graph, figure 5, shows that the modulator was stopped at 14:30. It was done to give people the possibility to carry out tests on the interlock system of MDK29.

The rest of the afternoon the RF formation was continued. However the RF power was limited by the multipactor effects which meant that from 1.3MW to begin with only 1.5MW was obtained at the end of the day.

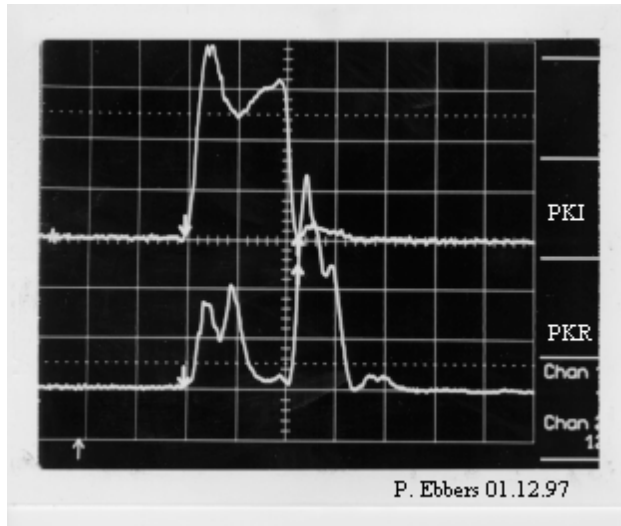
The MDK was left to run overnight with 1.4 MW measured on the PKI coupler. PPI pulse length of 2 μ s.

Following photos were taken at 1.5 MW. The signals are measured at the output of the 'Boîte C'. The scale is in Volts per division and only the Peak Power is given.



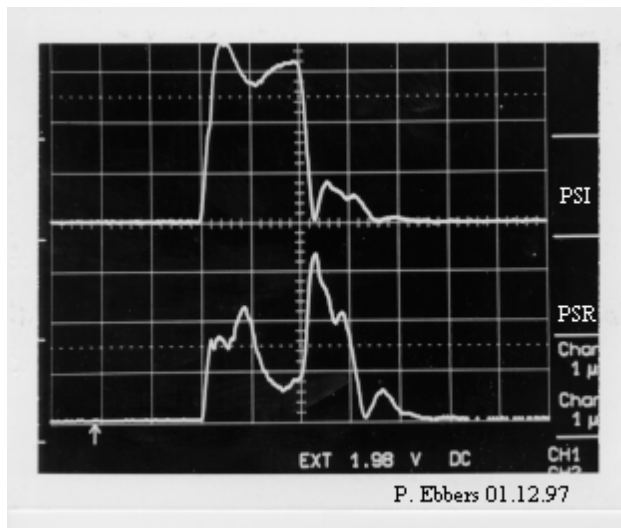
PPI: 0.1V /Div (100W)
PPR: 20mV/Div (10W)
Timebase: 1 μ s/Div

Figure 3: Input Klystron



PKI: 20mV/Div (1.5MW)
 PKR: 50mV/Div (150kW)
 Timebase: 1 μs/Div

Figure 4: Output Klystron



PSI: 0.5V/Div (1.2MW)
 PSR: 0.5V/Div (120kW)
 Timebase: 1 μs/Div

Figure 5: Input Section

Tuesday 02.12.97

During the night the modulator ran without any problem. Increasing the RF power to 1.5 MW makes the MDK stop too often so turned the RF power back to 1.4 MW. The PFN was increased to 25kV at 14:45 since the input amplifier was working too close to it's maximum.

During the day it was tried to increase the RF power but with some difficulties as can be seen in the graph on the next page. Finally in the evening the section was left with 1.7MW. The MDK ran overnight again only to stop due to reflected power at 19:30.

A problem we came across was the Hewlett Packard Peak Power Meter that seemed to be sensitive to differences in pulse length. When changing the length of the pulse the following digitised values were obtained:

- 1.8μs → 1.3MW
- 2.0μs → 1.5MW
- 2.3μs → 1.6MW

Nevertheless the video signal of the PPM worked correctly.

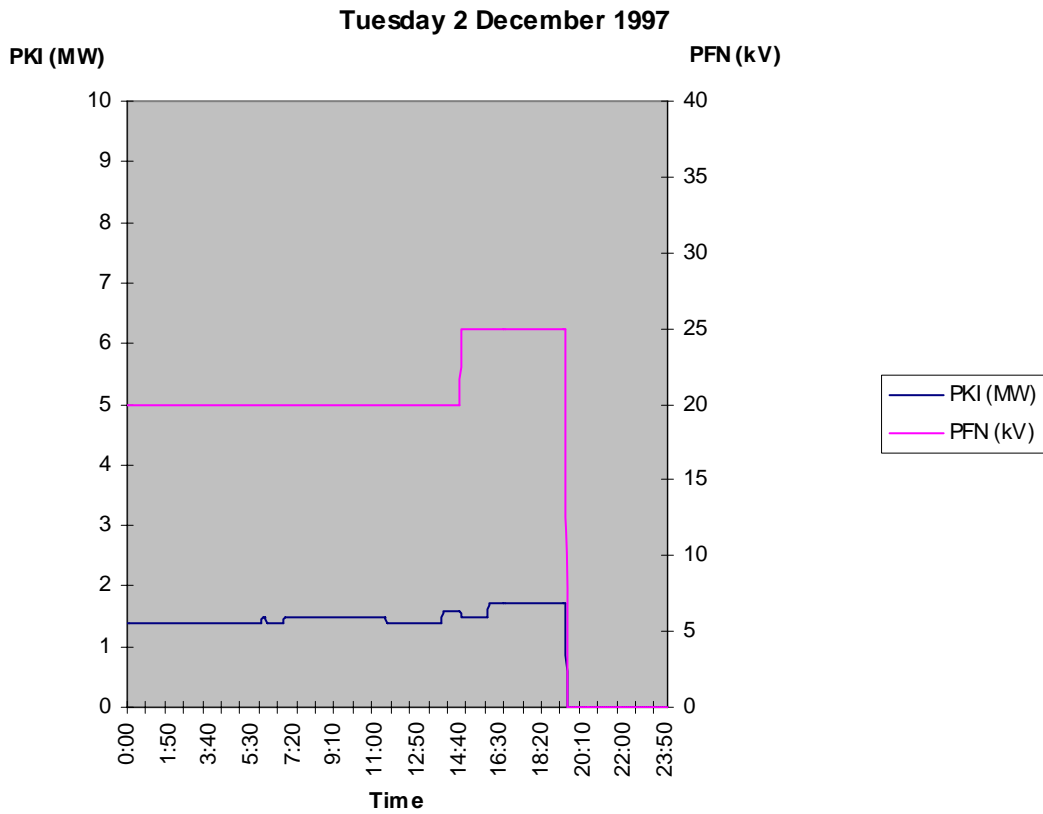
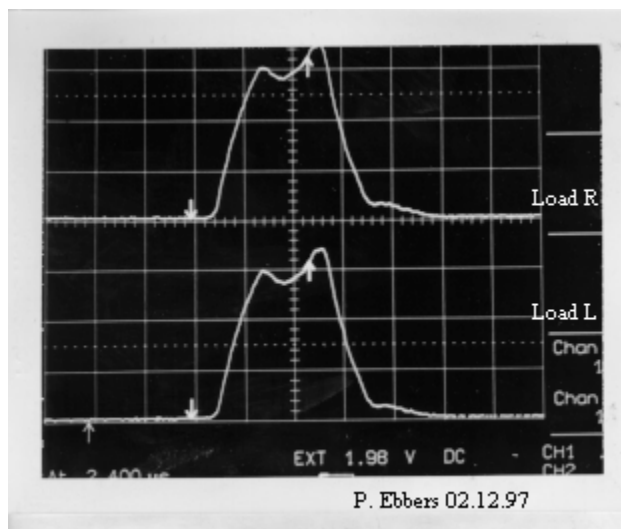


Figure 6: Graph of RF-power obtained on 2 Dec 1997



Load R: 0.5V/Div (700kW)
 Load L: 0.5V/Div (700kW)
 Timebase: 1 μ s/Div

Figure 7: Output section

Following photos were taken at 1.5 MW. The signals are measured at the output of the 'Boîte C'. The scale is in Volts per division and only the Peak Power is given.

Wednesday 03.12.97

The RF formation was picked up at 06:00 with a pulse of 1.8 μ s and 1.3 MW of RF power. Until the modulator stop at 08:50 the RF power was increased to 1.7 MW. The PFN was increased from 25kV to 30kV.

The modulator was stopped for CTF access to install attenuators on the sections and the loads. The attenuators that were placed:

Load L -20 dB

Load R -20 dB

PSI -20 dB

PSR -16 dB

In the afternoon the formation was continued but the Peak Power Meter (PPM) was replaced with a new Peak Power Analyser, the HP 8991A which is NOT sensitive to pulse length differences and repetition rates. With this new HP 4.4MW is measured.

When arriving at 4.8MW on the PKI coupler the MDK was stopped at 15:15 to set up measurement for reflected power interlock on MDK.

For this purpose the 50 Ω resistance was taken off the PKR coupler so all the power was reflected towards the klystron. The interlock was now set at 1.8 MW.

The rest of the afternoon 8.4MW was obtained but for the night the RF output of the klystron was regulated to give 8MW.

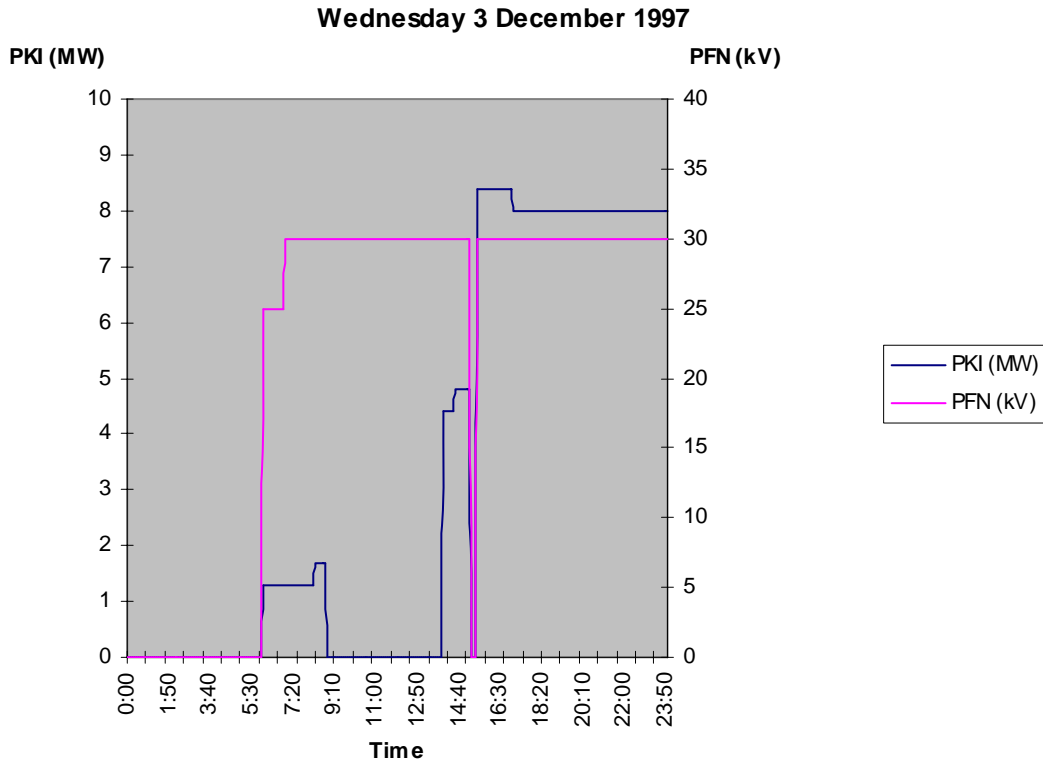


Figure 8: Graph of RF-power obtained on 3 Dec 1997

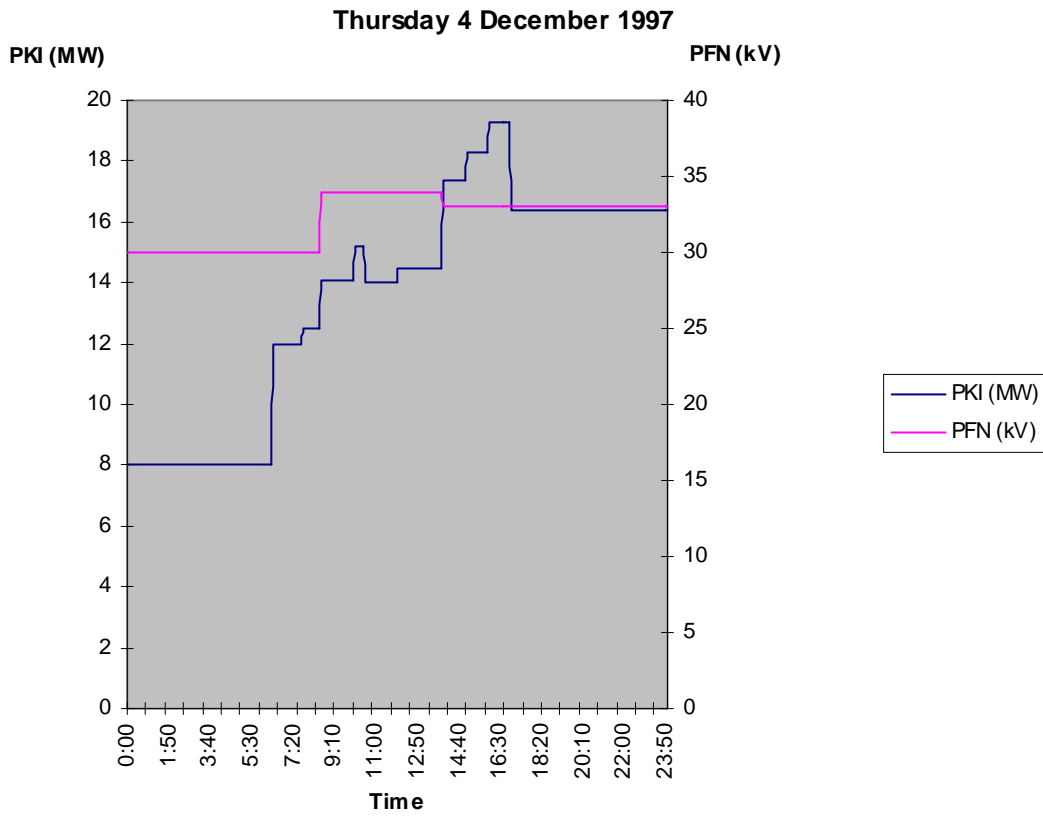


Figure 9: Graph of RF-power obtained on 4 Dec 1997

Thursday 04.12.97

During the night the MDK didn't stop. When increasing the RF power a lot of breakdowns occur at 12 MW. From this level onwards the RF power was gradually increased until 19.3MW at 16:00.

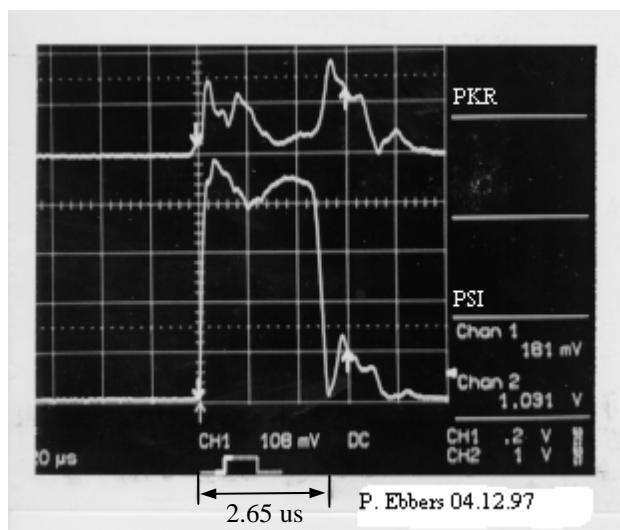
The reflected power interlocks were mainly due to the breakdowns in the beginning of the waveguide section.

At 08:30 the PFN was increased to 34kV but later on it was put back to 33kV since this was considered the maximum for the present 'old' modulator.

A measurement was carried out to determine the maximum power at the input of the klystron, PPI. For this the connection to the klystron disconnected and the input power was measured to be 170W maximum. This meant that the klystron was never saturated since the saturated region typically starts at 200W input power.

With the maximum power at the input of the klystron (170W PPI) the measurements with a rectangular pulse had nearly reached the end at 16:00. The measurements were limited by the klystron which PFN value is limited to 33kV.

Following photos were taken. The signals are measured at the output of the 'Boîte C'. The scale is in Volts per division and only the Peak Power is given.

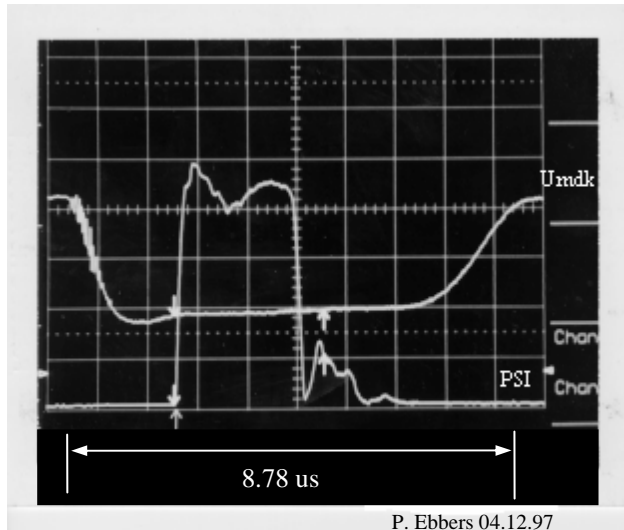


PKR: 1V/Div (1.6MW)
PSI: 0.2V/Div (19MW)
Timebase: 1 μs/Div

PKI = 19.3 MW

PSI pulse width measured

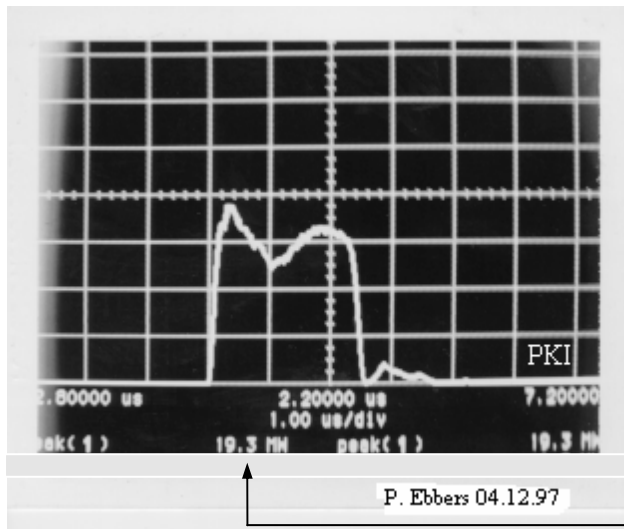
Figure 10: Section input and power reflected back into the klystron



Umdk(PFN): 100kV/Div
 PSI: 0.2V/Div (19MW)
 Timebase: 1 μs/Div

Umdk pulse width measured

Figure 11: The PFN pulse compared with the section input



HP Peak Power Analyser:
 PKI(linear scale): 5 MW/Div
 Timebase: 1 μs/Div

PKI = 19.3 MW

Figure 12: Output of the klystron

The modulator was left running overnight with 16.4MW on the PKI coupler.

Friday 05.12.97

The first stop shown on the graph on the next page is due to a reflected power interlock. The modulator ran until 04:40 in the morning with 16.4MW. The MDK was started again with only 10MW since there were too many breakdowns in the waveguide. Very soon the maximum RF power of 19.3 MW on the PKI coupler was reached and maintained for over an hour until an intervention took place on the MDK.

The SF6 in the first part of the waveguide was replaced since it had deteriorated with the breakdowns. An electrovalve for cooling of the first window on the MDK was changed since it caused problems when trying to reset after an interlock. The valve was tested with K.VPI2 and it seemed to work again.

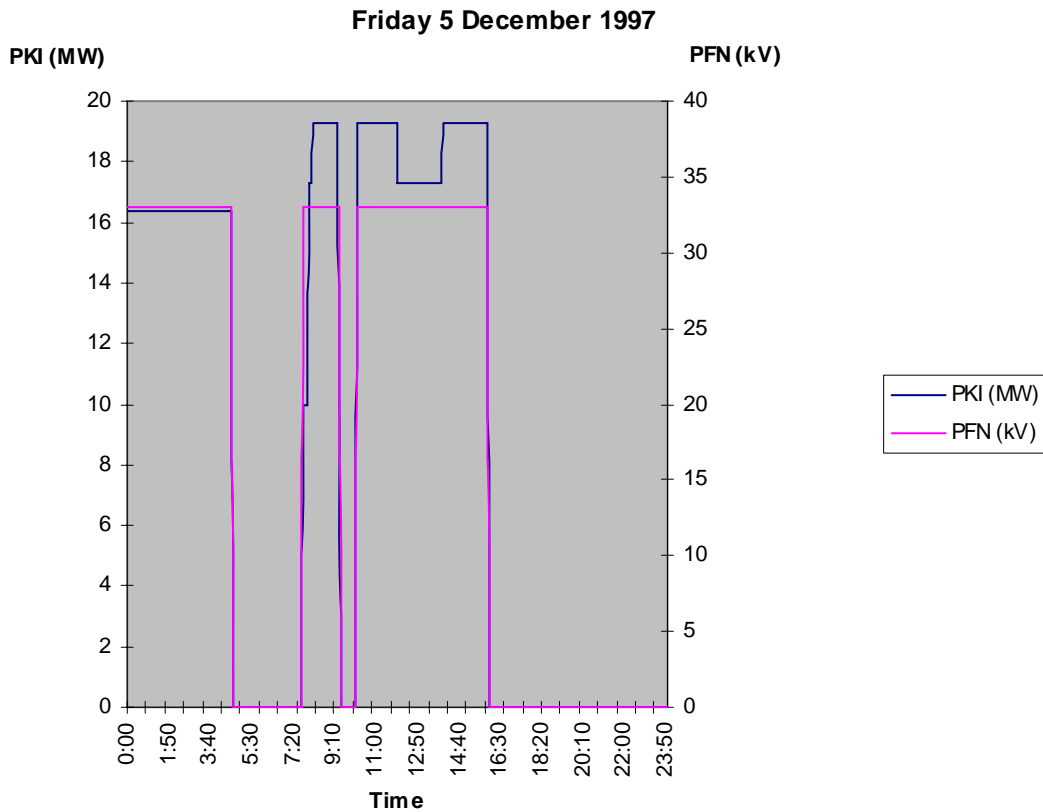


Figure 13: Graph of RF-power obtained on 5 Dec 1997

At 10:00 the formation was started again at 19.3MW when surveyed and at 17.3MW when not surveyed. Before stopping the modulator before the weekend the PPI signal at the input of the klystron was verified to be 180W.

Output power of the Thorn Amplifier	320W
Output power of Flexwell Cable 10m	240W
Output power at PPI Coupler	180W

The RF losses between the Flexwell cable and the PPI coupler can be reduced by low loss cables, if the klystron requires more input power than 180W.

Week 50 (RF formation done with variable ramps of input pulse and with LIPS)

Monday 08.12.97

No RF Formation was done since the day was spent on work on laser alignments in the machine.

Tuesday 09.12.97

The morning was lost due to a non interruptible Power Supply that got interrupted. The afternoon R. Bossart proposed to measure the phase linearity between the input and the output of the Klystron. The dynamic phase error due to the phase ramping between PPI and PKI was measured to be 15° .

Wednesday 10.12.97

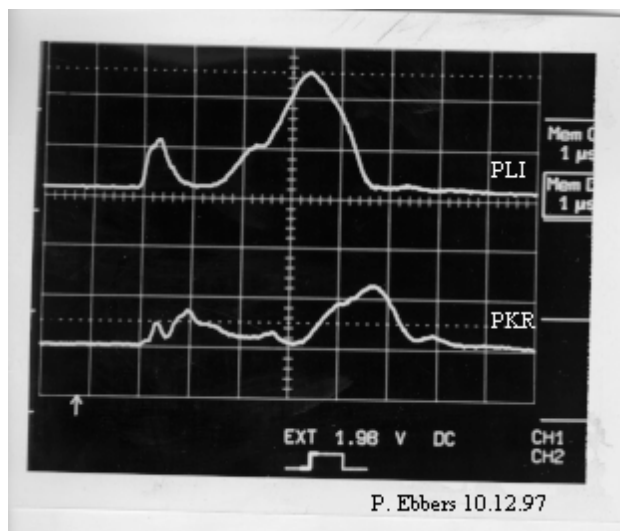
The RF formation started in the morning and the power was measured at the output of the LIPS. Gradually the power was increased to 11.1MW in the afternoon.

A synthesised function generator was used to change the phase of the klystron. The goal was to gradually change the phase of the signal at the input of the LIPS so the output of the LIPS, i.e. the input of the section would be more smooth. The phase input changed as follows (figure 15):

Phase change from 0 - 500ns is 33°

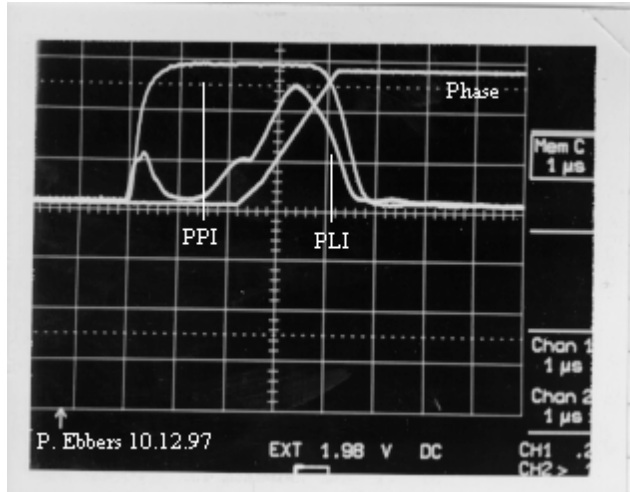
Phase change from 500 - 2000ns is 147°

Following photos were taken at 6 o'clock in the afternoon. The signals are measured at the output of the 'Boîte C'. The scale is in Volts per division and only the Peak Power is given. 6 o'clock in the afternoon.



PLI: 5MW/Div (12.5MW)
PKR: 1MW/Div (1.2MW)
Timebase: 1 μ s/Div

Figure 14: Incident power of LIPS and the power reflected back into the klystron



PPI: 0.1V/Div (150W)
 PLI: 0.2V/Div (12.5MW)
 Phase: 60°/Div
 Timebase: 1 μs/Div

Figure 15: Klystron input power, LIPS incident power and the phase change of the input

The shoulder during the raise of the PLI signal in figure 15 is due to the first phase vector of 33° during the 500ns. The Modulator was left overnight with 9 MW power on PLI coupler. Due to a reflected power interlock the modulator stopped at 00:00. The cause was a breakdown in HSC1 section.

Thursday 11.12.97

In the morning the modulator was restarted at 11.1MW and ran without a lot of problems until the stop at 10:30. Until midday there was an access into the machine so the formation had to be abandoned.

In the afternoon the RF power was gradually increased up to 18.2MW at 14:30. The reflected power was 1MW.

It has to be noted that an attenuator of 3dB was added to the PKR coupler. Instead of 74 dB with which the reflected power interlock of the MDK was regulated at 1.8MW, we had now 77dB. This meant that double the reflected power was allowed back into the klystron; 3.6MW.

For these settings the maximum level of the 'boîte C' output were the following:

- 1.8MW \cong 30mW which gives 1.5V
- 3.6MW \cong 60mW which gives 2.3V

Until now there were mainly breakdowns in the LIPS.

At 15:00 the RF formation was continued after the MDK was stopped for 15 minutes due to an access into the machine. The RF power reads 17.7 MW on the PLI coupler.

Some measurements were done with low pass filters (see figure 20):

Peakpower: PKI = 9,44 MW
 PLI = 16.8 MW

$$\frac{P_{OUT}}{P_{IN}} = \frac{PLI}{PKI} \approx 1,8$$

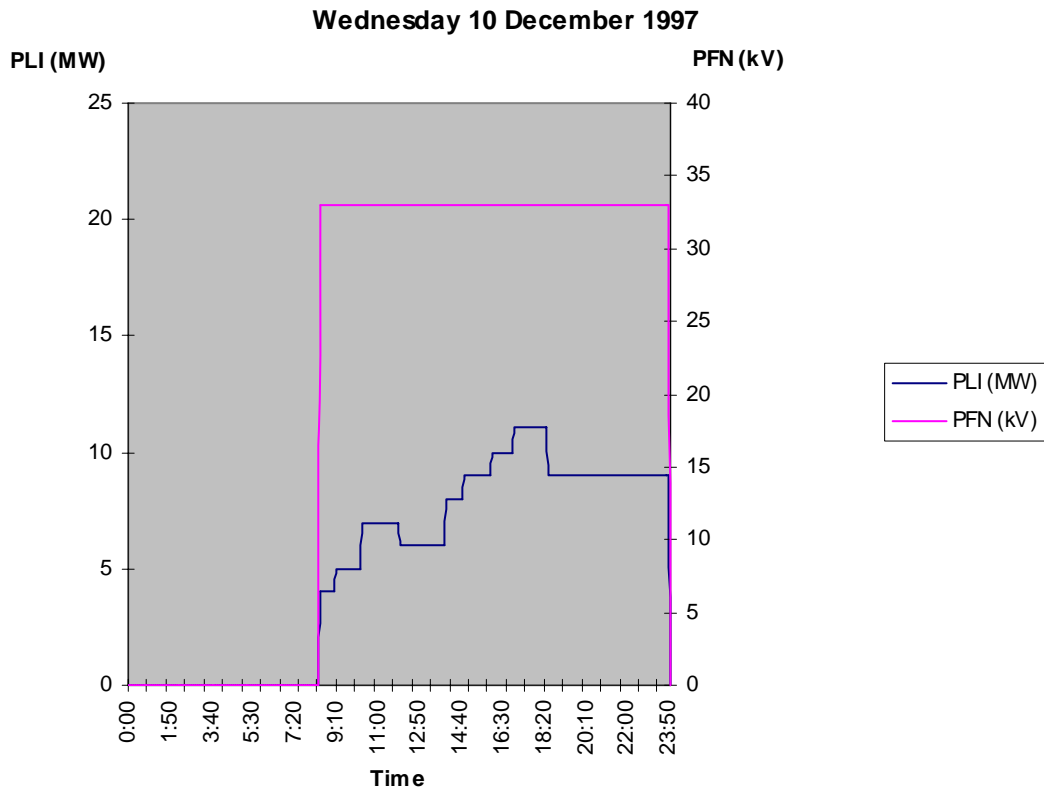


Figure 16: Graph of RF-power obtained on 10 Dec 1997

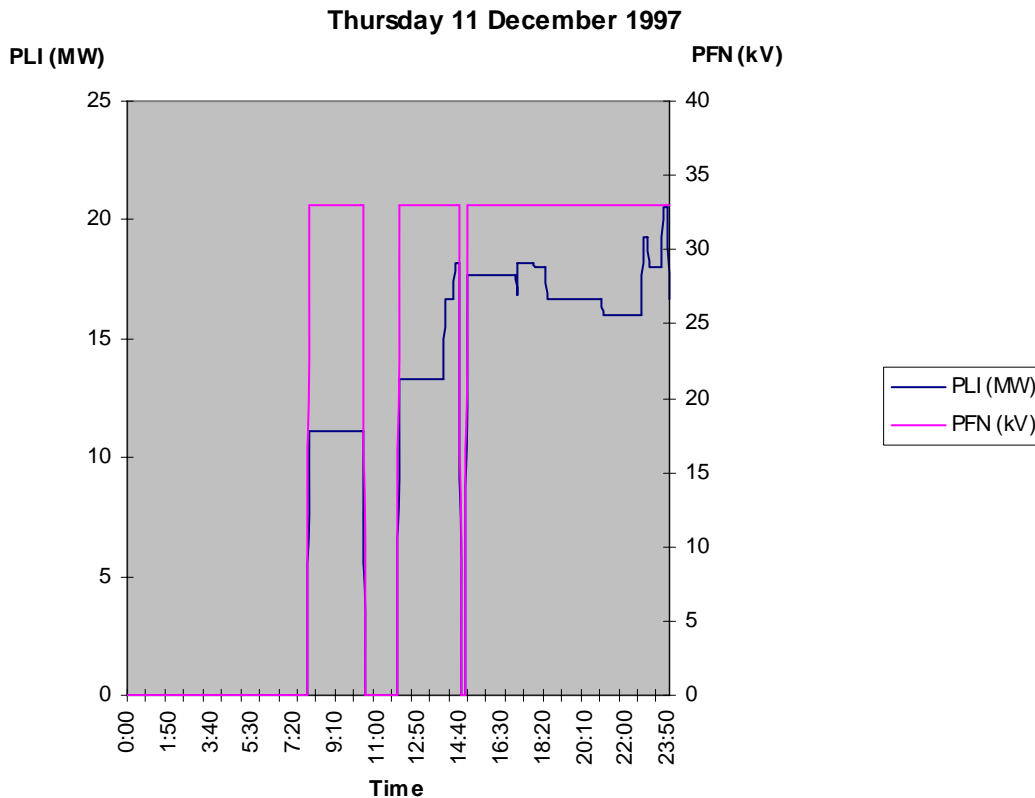
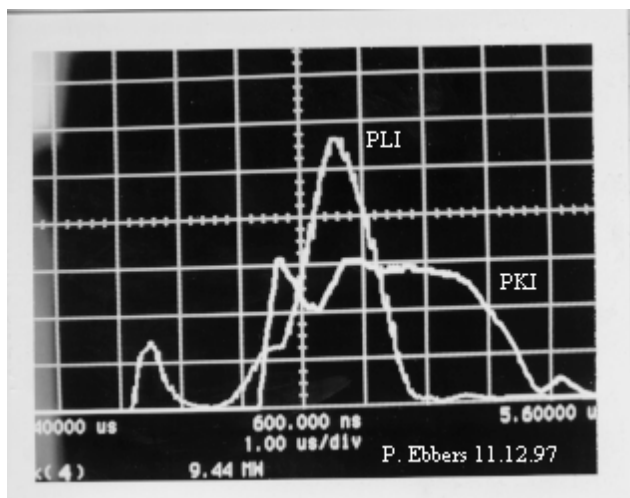


Figure 17: Graph of RF-power obtained on 11 Dec 1997



PLI: 3MW/Div
 PKI: 3MW/Div
 Timebase: 1 μ s/Div

Figure 18: LIPS incident power and Klystron output.

The RF conditioning was continued until midnight. This time the breakdowns in the section HCS1 became more frequent. Due to these breakdowns the vacuum in the section suffered quite a lot so therefore the RF power had to be decreased several times to regain a stable situation. At roughly 23:00 a reasonably stable 19 MW was reached. Just before leaving the modulator to run overnight 20.5MW was tried but was not stable.

The modulator was left with 16.7MW on the PLI coupler but unfortunately stopped already at 02:00. The cause was reflected power due to breakdowns in the section HCS1 due to the high vacuum pressure of 10^{-7} Torr.

Friday 12.12.97

The modulator was started again at 08:00 with 18.0MW on PLI coupler. Most of the period until the modulator was stopped at 11:00 the PLI power was 19.2MW with occasional breakdowns in section and LIPS.

The formation was halted to change the SF6 again. There had been a lot of breakdown in the beginning of the waveguide section which is under SF6. The breakdowns make this gas deteriorate.

During the first period of the afternoon (until 14:30) the modulator had been running with 20.0MW on the PLI coupler, without stopping due to an interlock. With 22.3MW occasional breakdowns in the section are observed.

Finally at 17:00 23.0MW is obtained but soon after that the systems are switched OFF for the CTF shutdown 97/98

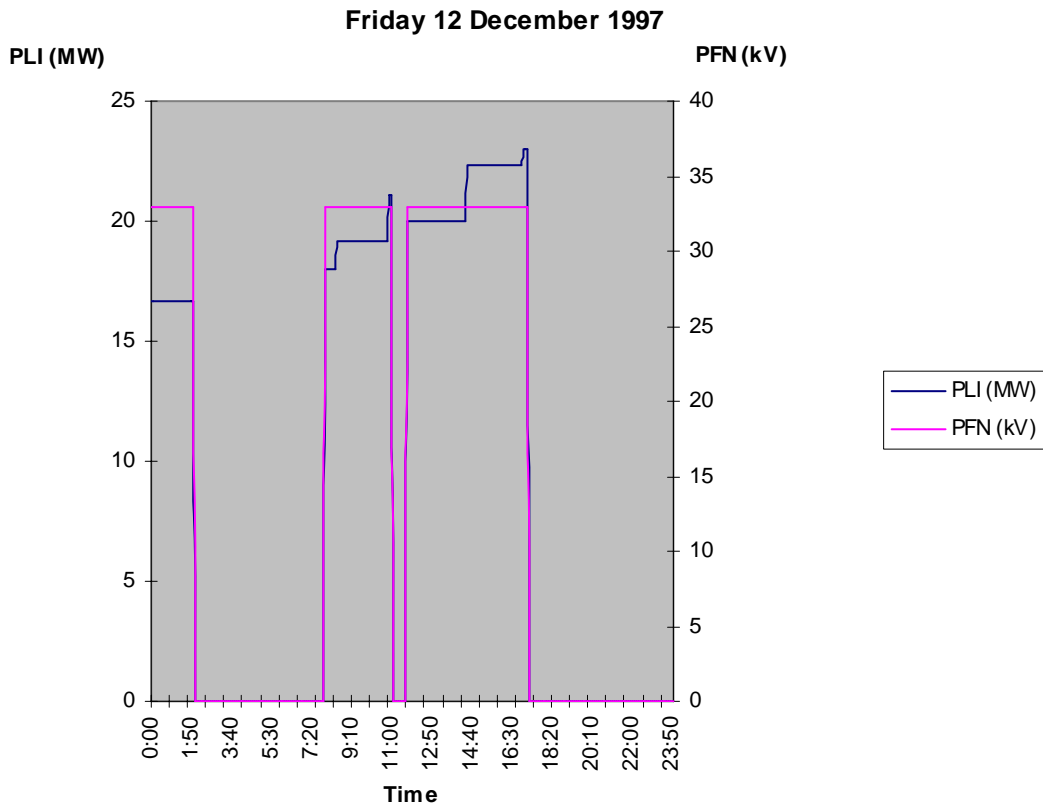


Figure 19: Graph of RF-power obtained on 12 Dec 1997

Conclusion

Without LIPS

During the first week the 19.3MW was obtained without too many problems. However one has to realise that this was the maximum power possible since the conditioning was limited by the input amplifier which delivered 170W and is not saturating the MDK at 33kV. More important was the limitation by the PFN of the klystron. It could not be increased to more than 33kV.

With LIPS

The second week there was a lot of time lost by machine accesses and major breakdowns in the LIPS. Finally 23.0MW was obtained on the PLI coupler. The electric field we arrived to obtain in the accelerating sections is far from the nominal 80MeV/m. Some 30% was reached.

During the shutdown 97/98 every effort will be made to use the automated way of RF conditioning that was used on GUN4 in the CTF on the HCS1 as well. Some development/installation will have to be done on both hardware and software side.

Distribution:

Daniel ALLARD;
Simon BAIRD;
Rudolf BOSSART;
Hans BRAUN;
Michel BROUET;
Jean-Pierre DELAHAYE;
Bruno DUPUY
Roland GAROBY;
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