# 30 GHz RF Power production in CTF3

(Technical aspects, RF commissioning results in 2004 and hardware development).

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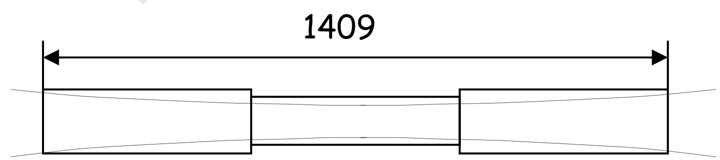
Design parameters (2003):

- Initial beam energy : ~70 MeV
- Power to be produced by PETS at 30 GHz: ~ 100 MW
- Maximal electric field on a surface: < 150 MV/m
- 30 GHz RF pulse length (CLIC spec): ~140 ns
- Beam current : 5 A
- Beam stability issues

After many iterations, basically following beam stability simulations, the structure architecture was chosen to be aligned to the beam waist profile along beam trajectory. Finally the three structures with two different apertures 9 mm -> 6.7 mm – 9 mm were adopted. The cell dimensions and structures length were both optimized to satisfy the design parameters together with low beam losses. With this choice, no damping of the transverse HOM is needed.

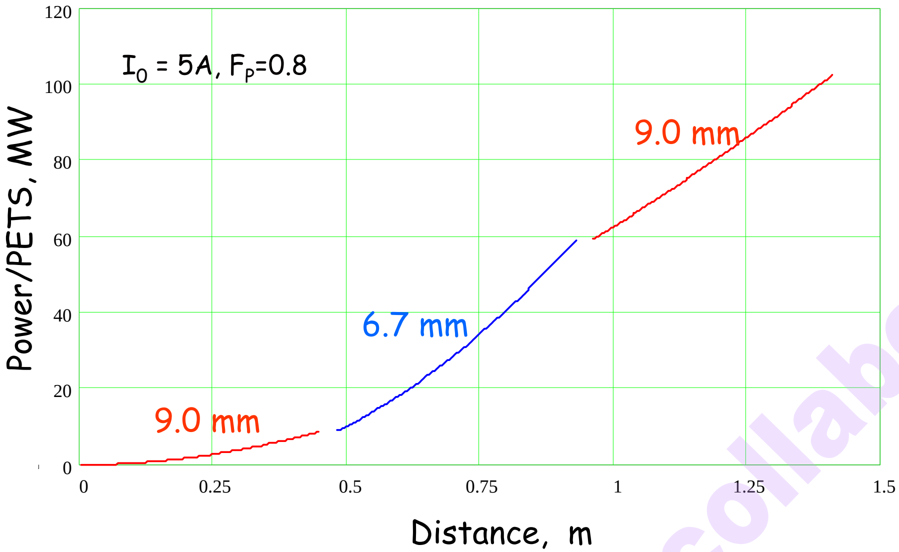


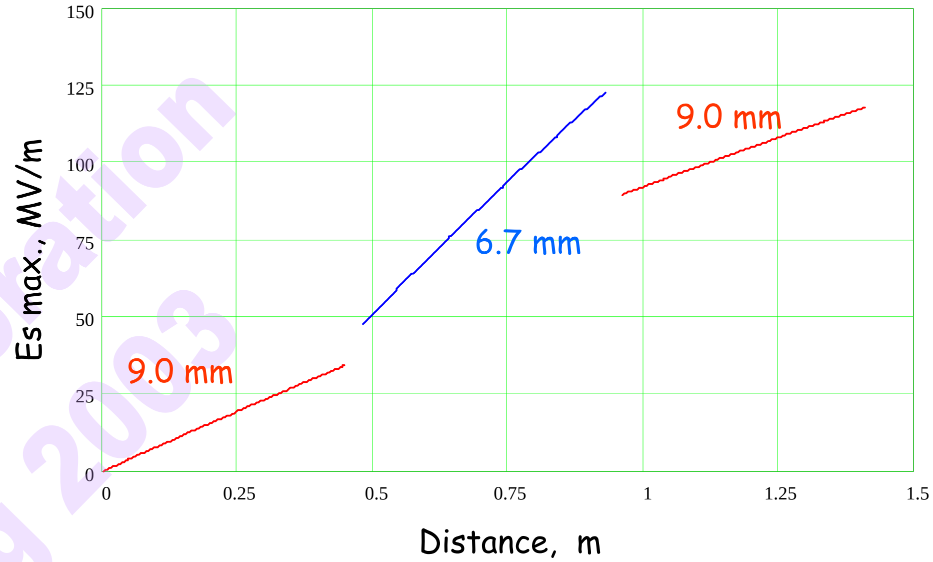
all three structures have equal length (130 cells)

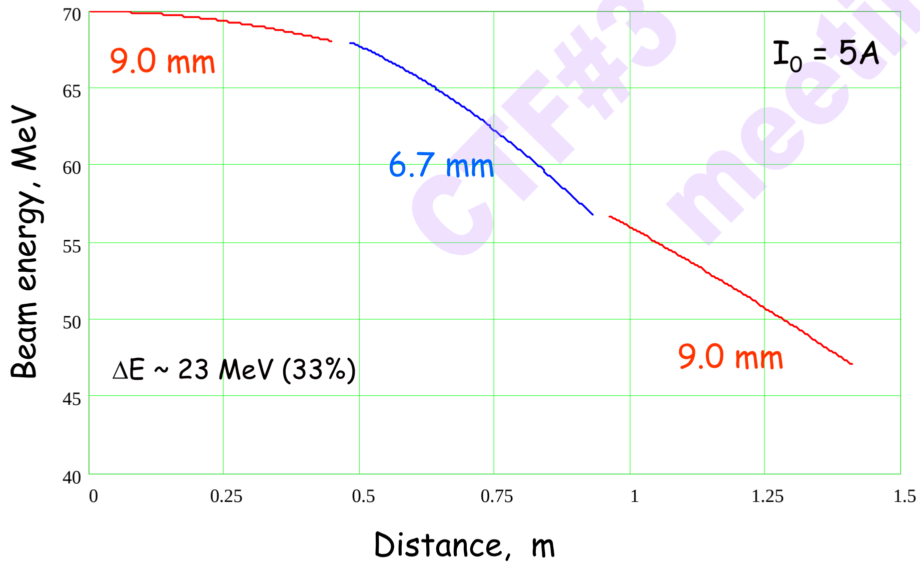



9.0 x 6.7 x 9.0

# 30 GHz power production in CTF3 (as expected)




$$\text{Power}_{PETS}\,[\text{MW}] = 4.762\text{x}(I[A])^2\text{x}F^2$$

$$\text{Power}_{Load}\,[\text{MW}] = \text{Power}_{PETS} \times \eta_T$$

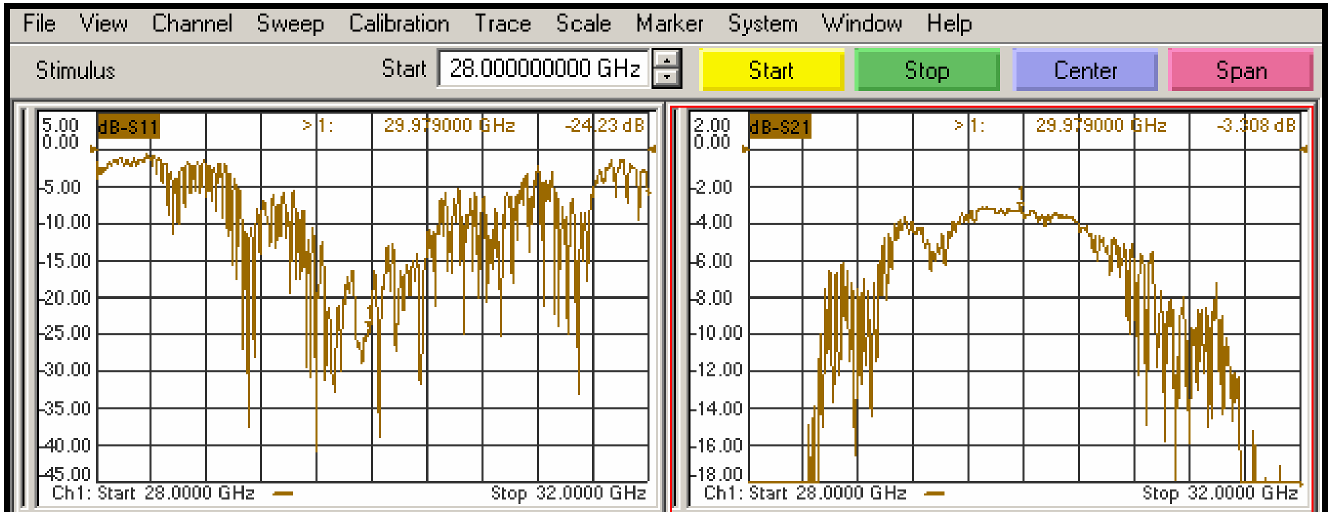
$$\eta_T = 0.86\text{x}0.85 = 0.73$$

WG components — Power transfer line

~ 87 MW at 5A into the load

# 9mm x 6.7mm x 9mm PETS

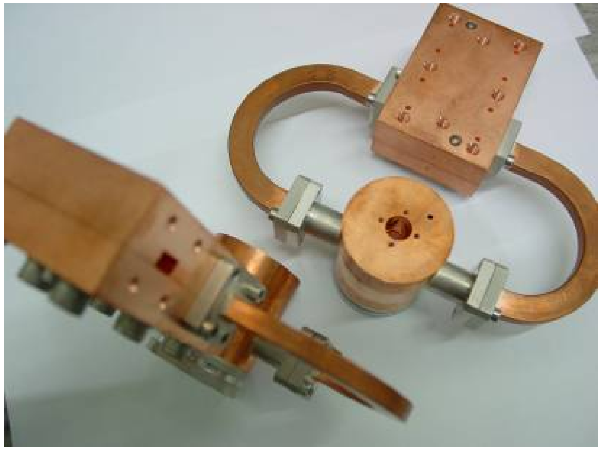
## S-parameters

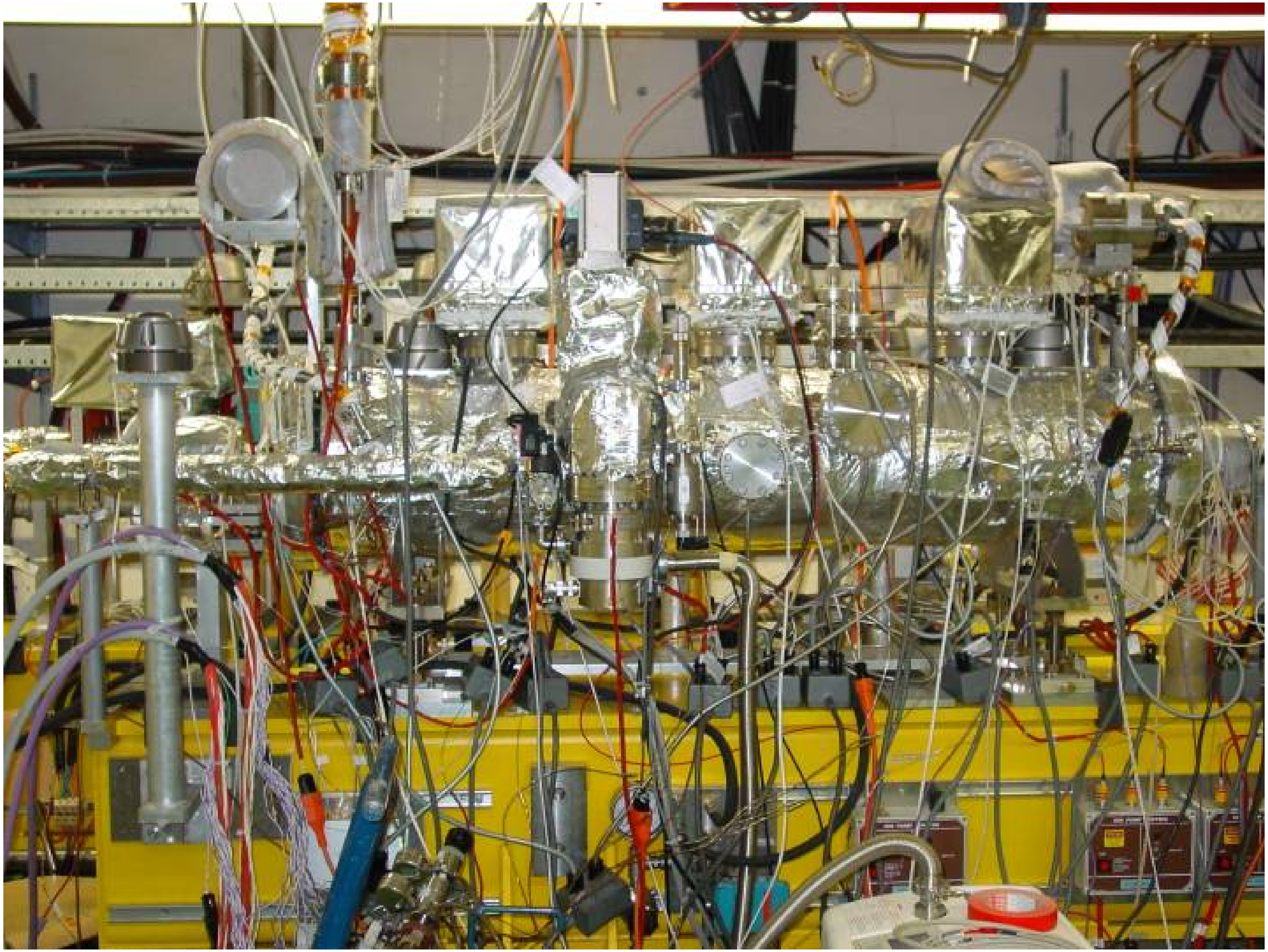




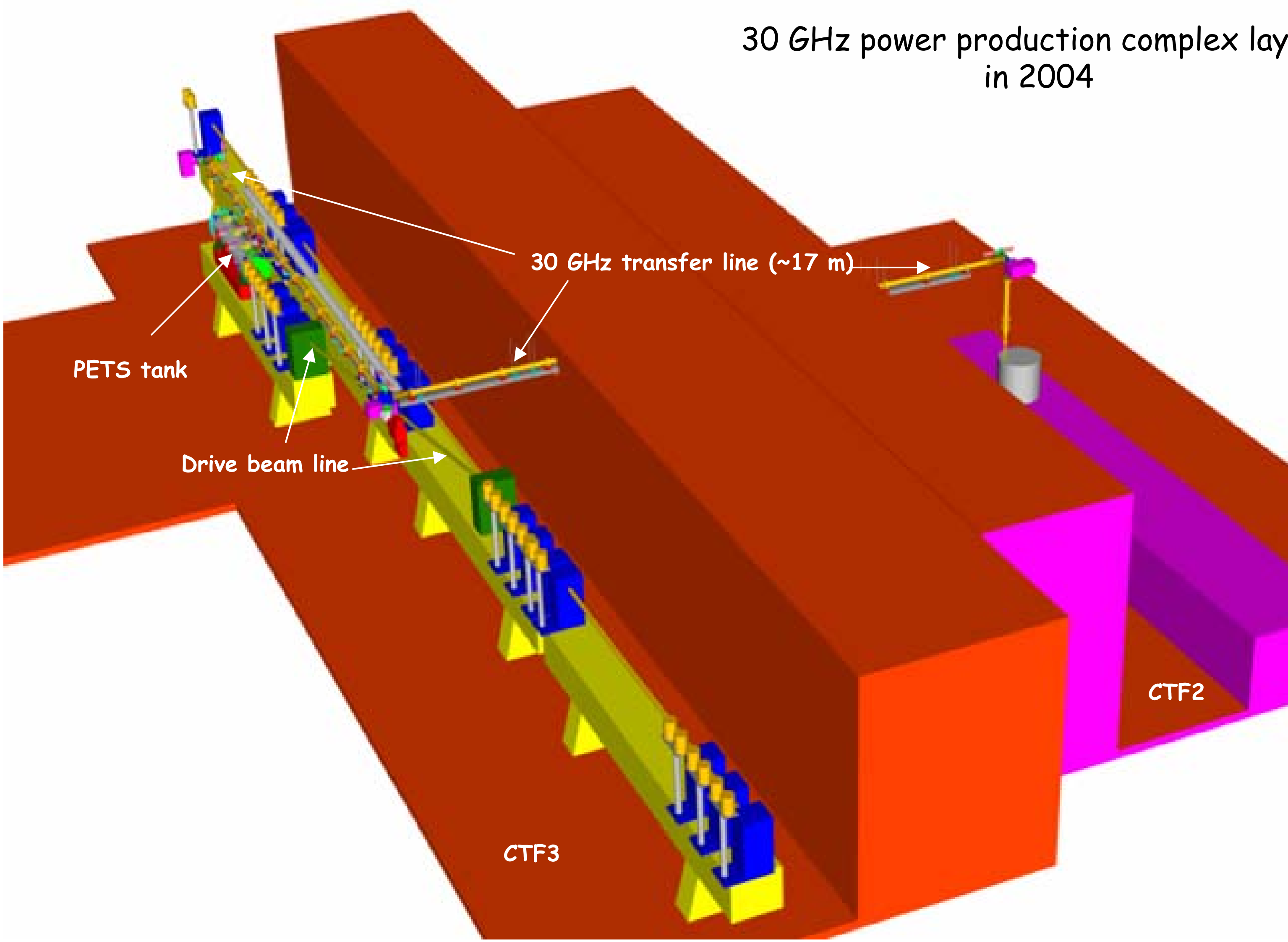
## PETS in vacuum vessel

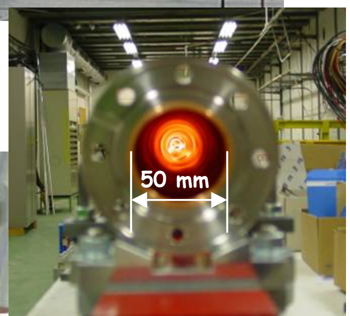
## PETS Power extractor

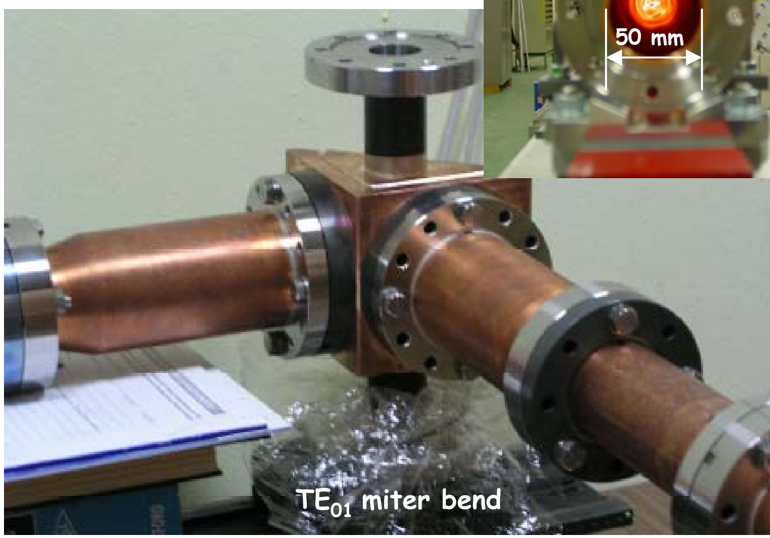




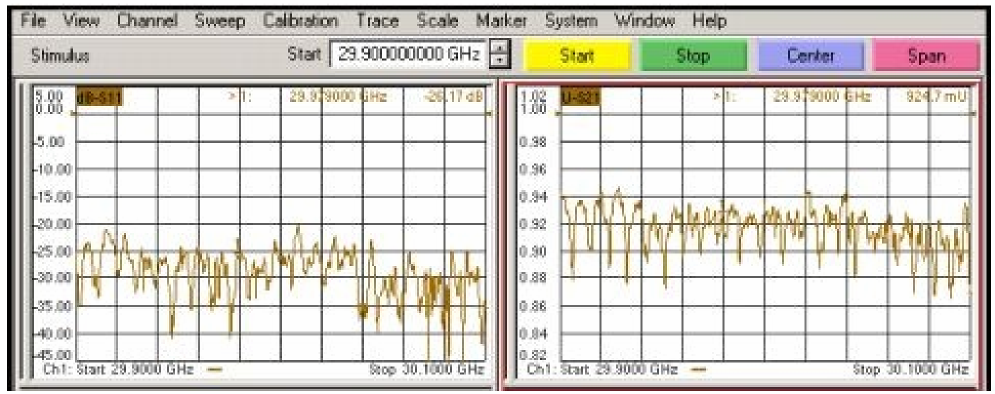
# 30 GHz power production complex layout in 2004



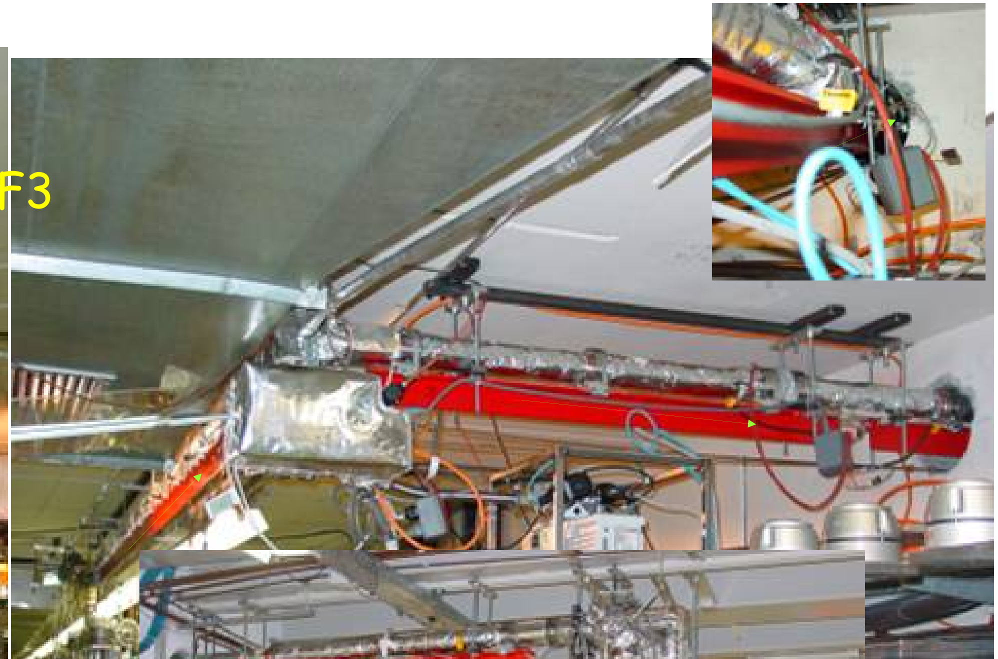




## Low power test setup in CTF2




Efficiency:
Expected – 88%
Measured – 85.5%

# 30 GHz power transfer line (continued)


Total (round-trip) group delay of the line of about 120 ns. This allowed us to decouple the processing events in CTF2 form power production in CTF3 during this period.

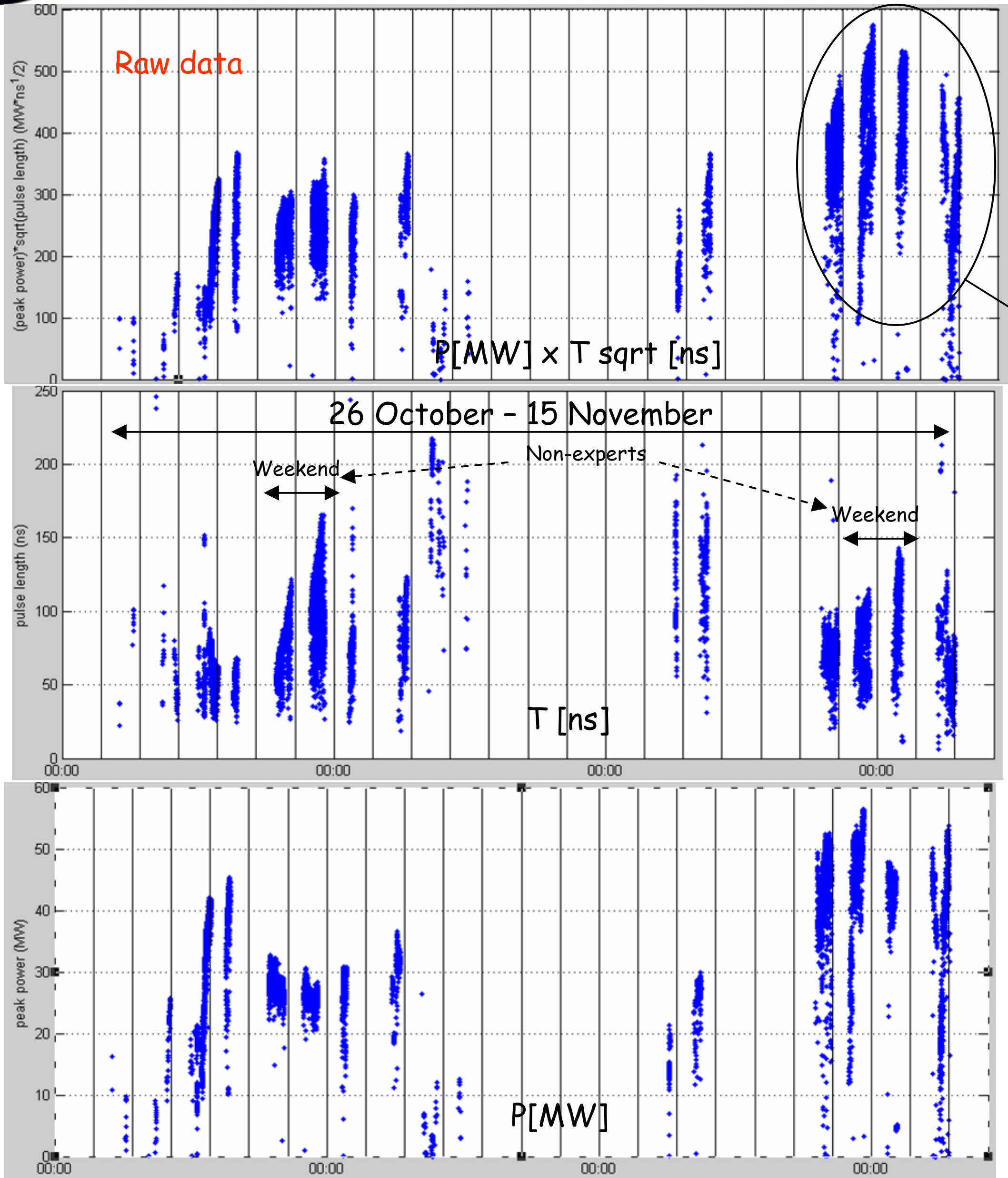
## General remarks:

**#1**. The peak power produced is a directly coupled to the beam current delivered. That is why it was very complicated to operate at a programmed power level. The pulse length was practically a free parameter.
**#2**. It was observed, that processing via increasing the RF power for the constant pulses length goes faster than increasing pulse length for the constant RF power.
**#3**. At any stages of processing the efficiency of drive beam current transport through the PETS was about 80% up to 5 A and ~ 60% at 6 A. Rep rate ~16 Hz was normally used during "routine" conditioning.
**#4**. The "decoupled" period of 120 ns (due to delay time of the transfer line) was in general more comfortable for the processing.
**#5**. The behavior of the signals during breakdown very often showed rather different character compared to that it was normally observed early in CTF2 experiments. In brief, we could see many consequent sharp cuts of the forward pulse together with overall pulse shortening. Perhaps, because this was the first operation with a such long pulses (>15 ns).
**#6**. During the later period of processing the vacuum activity was reduced significantly.
**#7**. Unexpected generation of 66 GHz component brought quite a confusion at the early stages of commissioning, especially for diagnostic. The 66 GHz impact on processing regime is also not well understood.
**#8**. It was observed that heavy breakdowns affect the drive beam transport efficiency.
**#9**. The first experience with 30 GHz RF phase switching was not completely successful, because of the residual beam energy difference between the two time bins, which could not be compensated sufficiently (especially for shorter bunches).
**#10**. Calibration of all the measurements still remains a very important issue for the future operation. It is planned to install calorimetric RF power measurements for the next CTF3 run in 2005.

## General results:

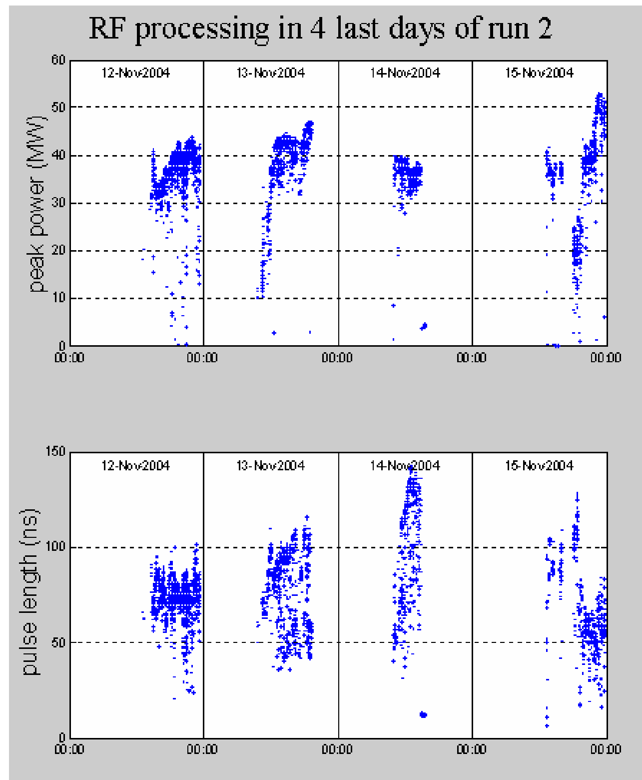
The CTF3 PETS together with transfer line and other waveguide components were processed up to 50 MW x 80 ns (40 MW x 140 ns) RF pulses into RF load in CTF2 in ~40 hours. This corresponds to maximum of about 70 MW RF power generated by PETS itself in CTF3 (compare this to 100 MW x 140 ns designed).

# Commissioning history

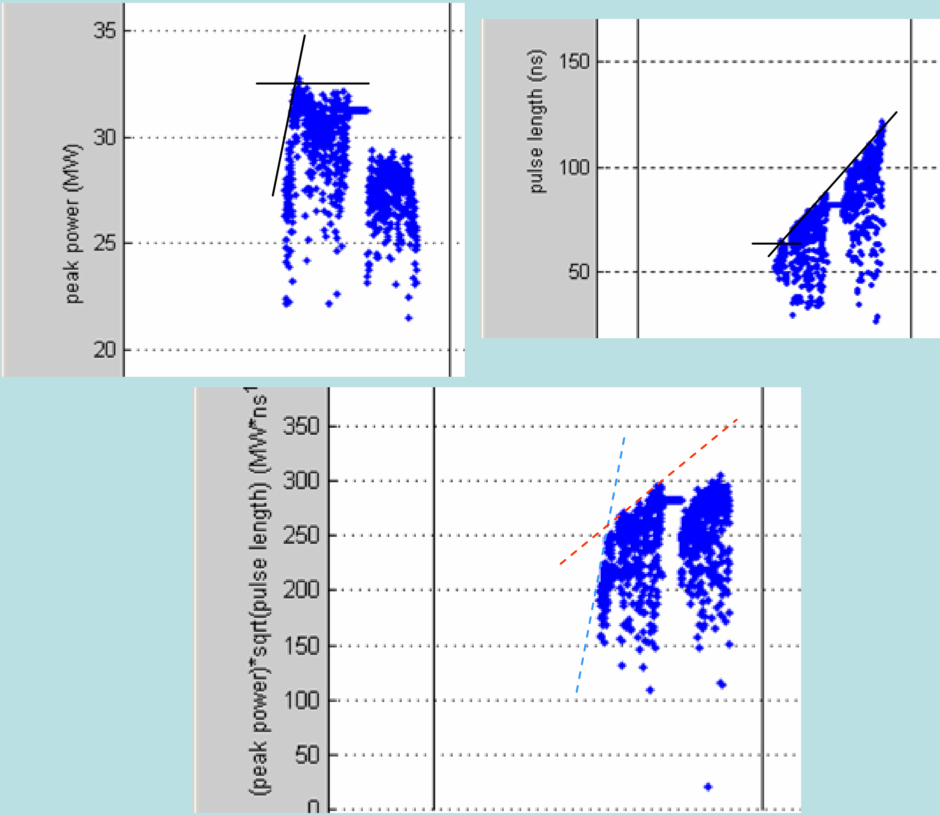



Total processing period was about 2 weeks and about 40 hours. During most of the time RF calibration errors brought ~ 20% overestimate in a power level.
From experience, beam setting time was ~ 30-50 % of conditioning period.

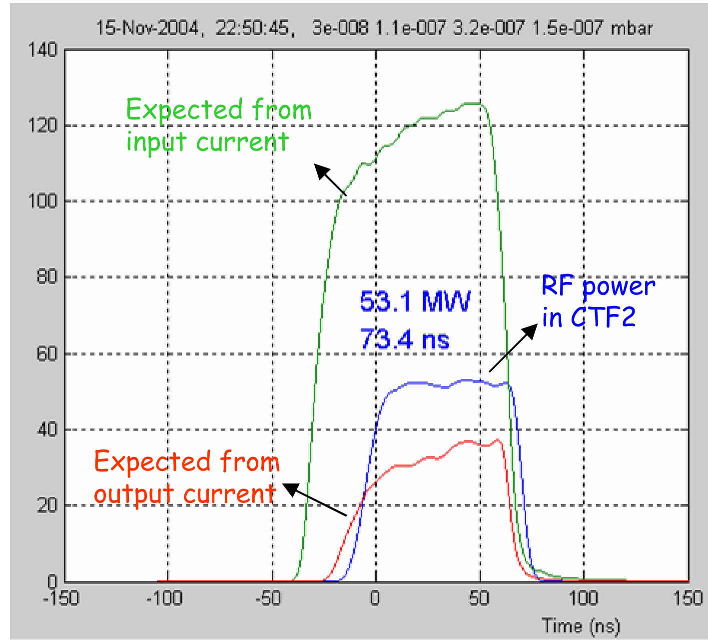
After re-calibration:



RF power versus pulse length



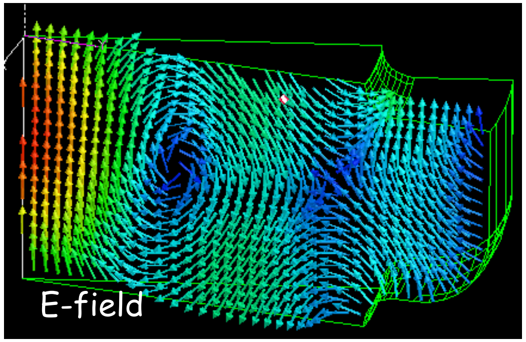

Drive beam and RF pulses envelopes measured at last day of commissioning



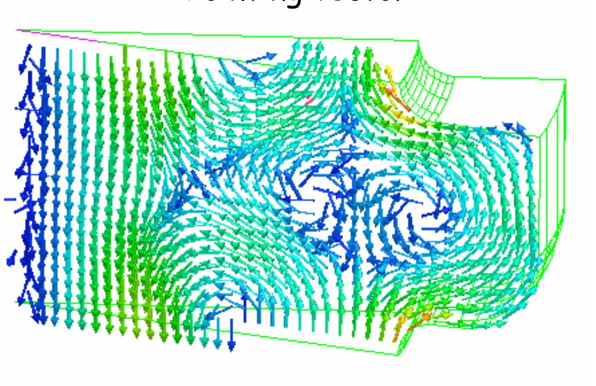
In a 1-st Run, following the fact that there was no any dependence of the detected signal amplitude in the extractor differential arm on the 30 GHz attenuator settings, it was discovered that 66 GHz frequency was presented there (successful power generation at 22-nd harmonic !).

| | | |
|---|---|---|
| F | 66 GHz | 30 GHz |
| R/Q | 356 Ohm | 5870 Ohm |
| Vg | **0.12 C** | 0.398 C |
| Ph/cell | 264 | 120 |

F=66.0 GHz 'complex' mode

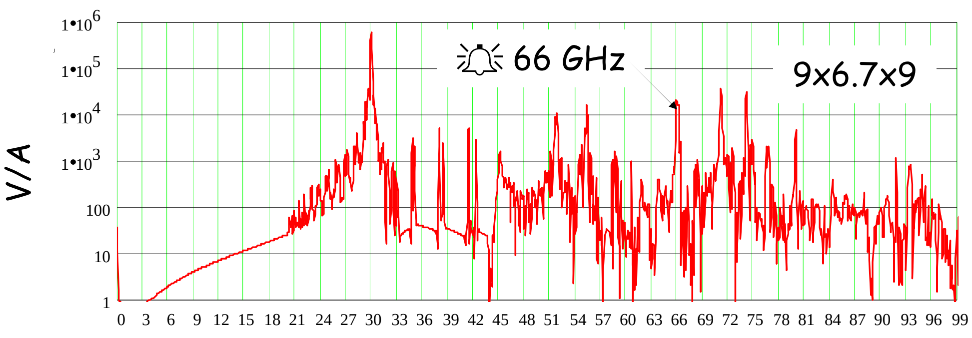


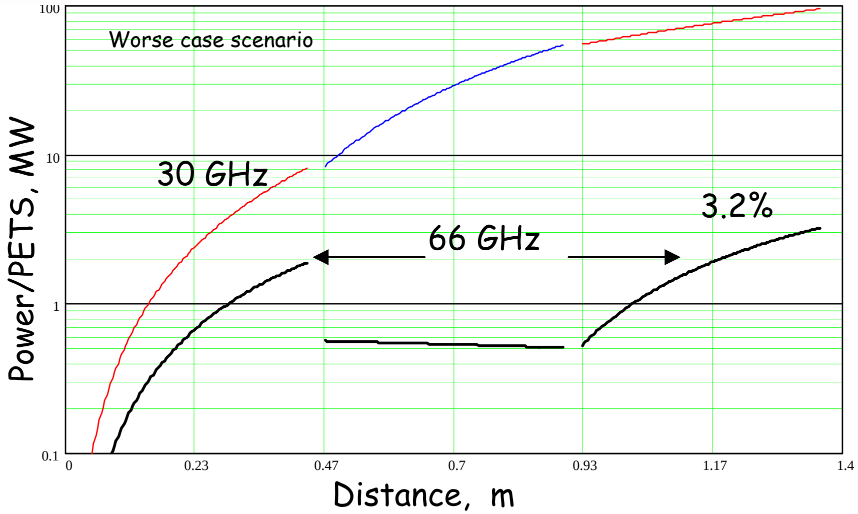

Pointing vector



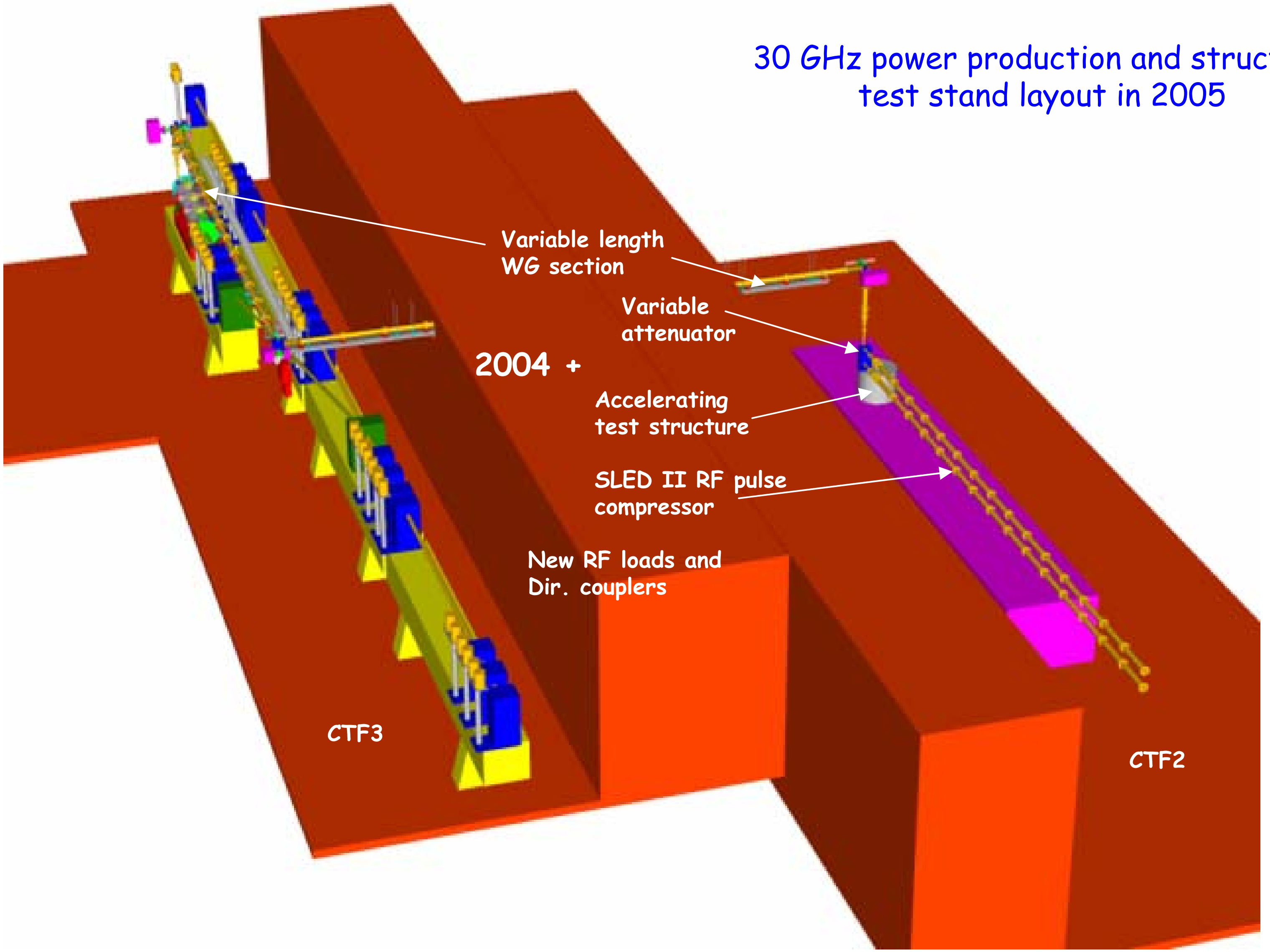
Power produced ($F^2 = 1$) ~ $R\omega/(Q \times Vg)$. Compared to 30 GHz this gives for equal length and current only 2.5 times less RF power.

PETS impedance by GDFIDL



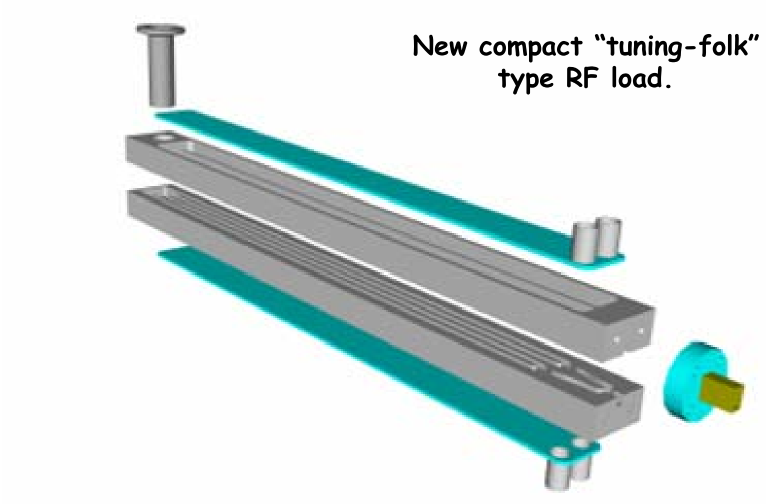



# 30 GHz power production and structure test stand layout in 2005

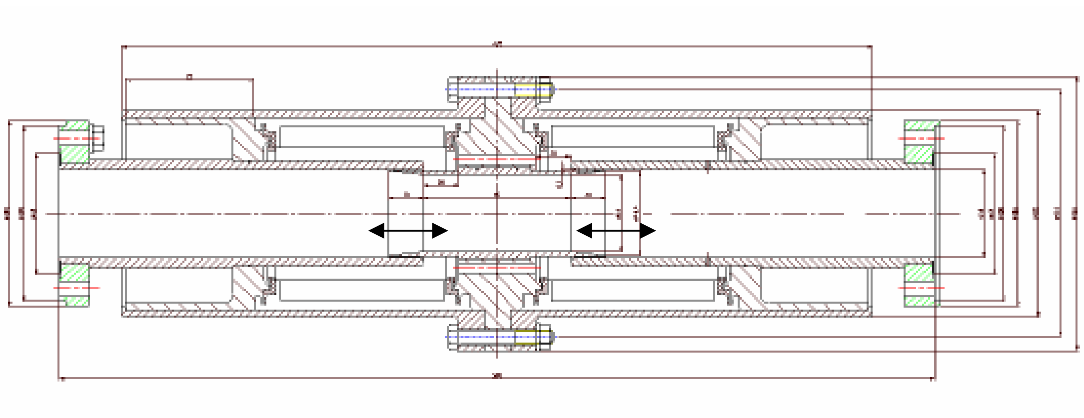


# New RF accessories

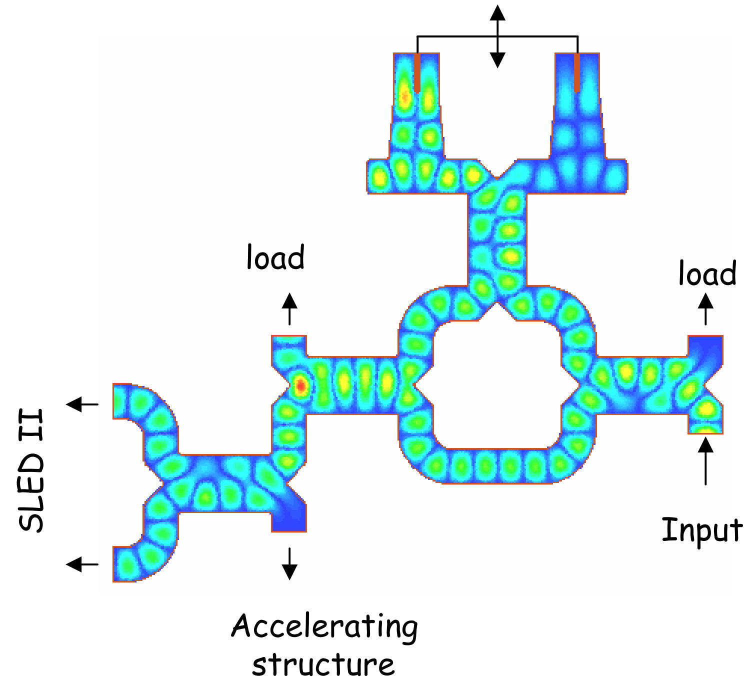
**New compact "tuning-folk" type RF load.**



**Variable (4 cm) length H01 WG section**

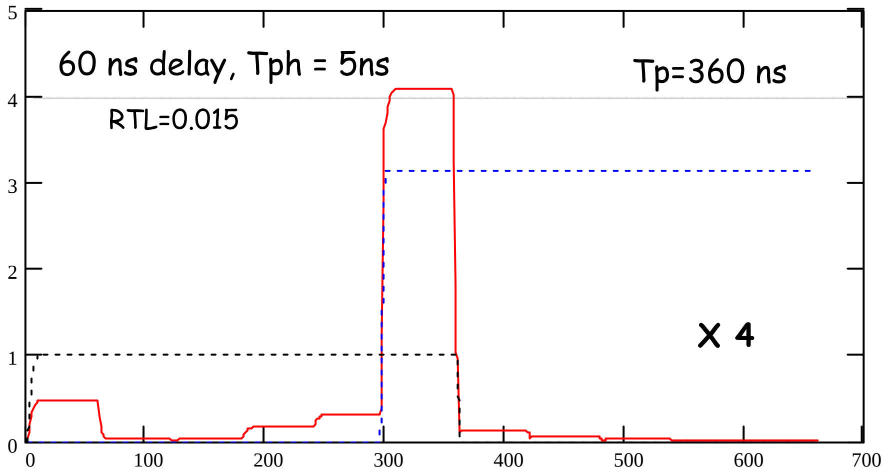


**NLC-type variable attenuator network**

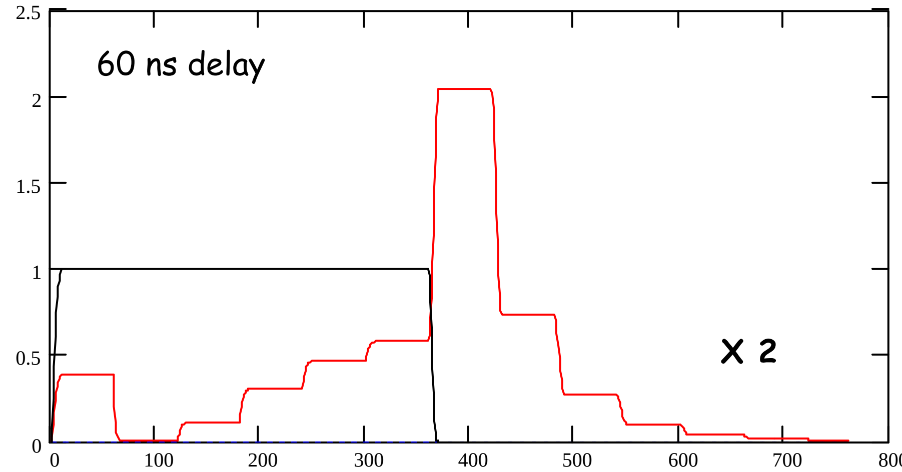


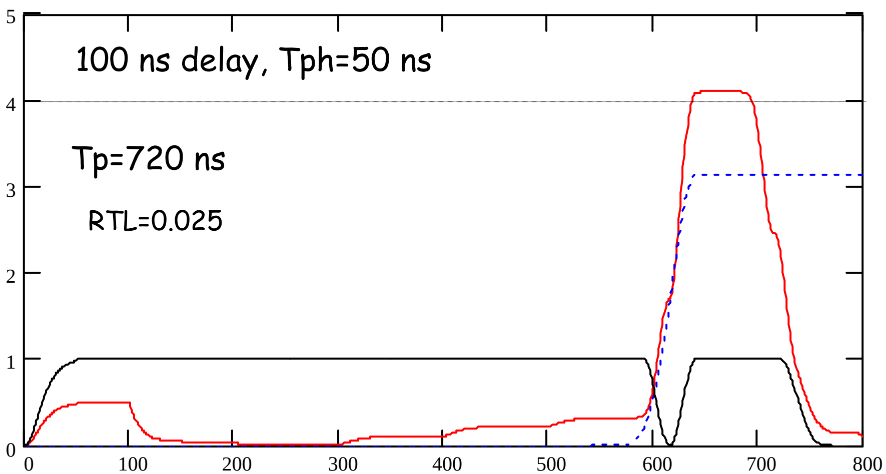
# 30 GHz RF pulse compression

#1. With Phase flip $180^0$ (60 ns flat top)




#2. Without Phase flip (60 ns flat top)




The use of SLED II type pulse compressor for 30 GHz RF power production enable us to increase considerable the peak RF power needed for the CLIC accelerating structure high gradient test, if the longer pulses (up to 700 ns) will be available from CTF3 PETS.
The TE01 transfer line demonstrated reliable performance in 2004. The pulse compressor based on the same modes-manipulation technology was ordered from GYCOM and will arrive in February 2005.