



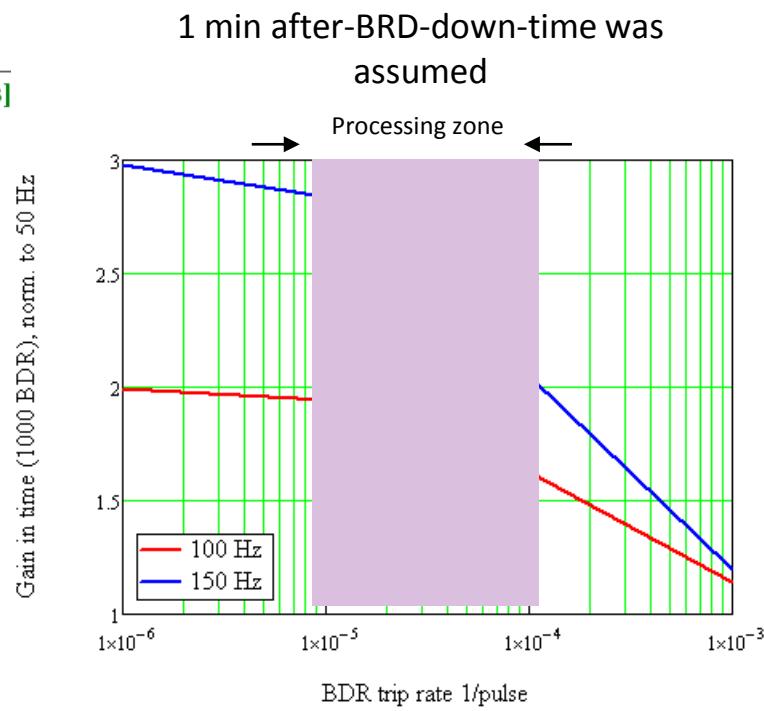
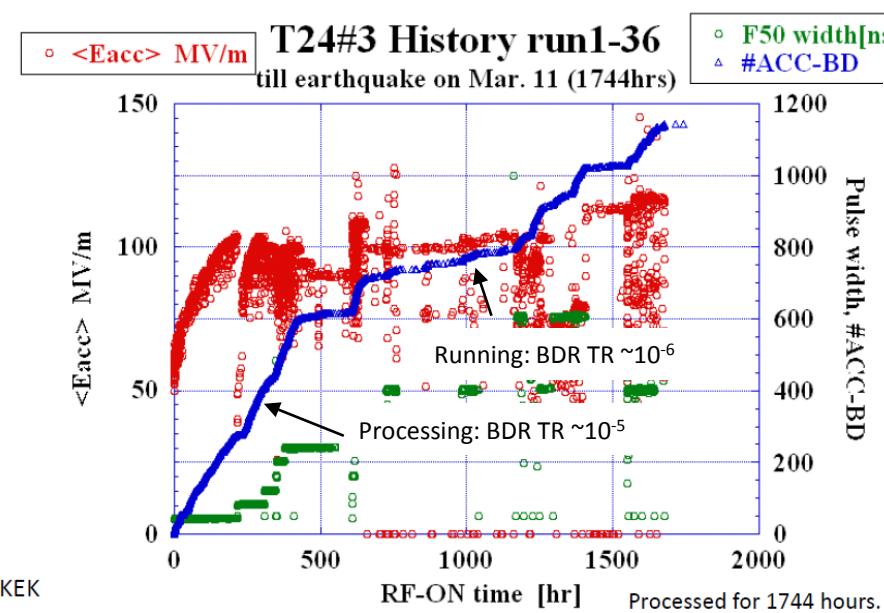
# Application of the moderate peak power (6 MW) X-band klystron's cluster for the CLIC accelerating structures testing program.

I. Syratchev



# Could the testing period be reduced by increasing the repetition rate?

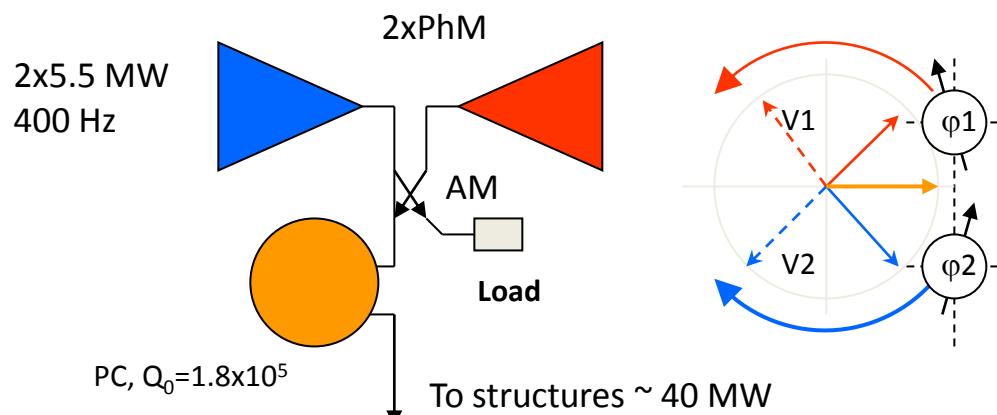
- 50 MW klystron. The XL-4 klystron was tested at 120 Hz and reduced pulse length - 1000 ns. To make it to operate reliably at a full spec some modification of the RF window and collector will be needed?
- Accelerating structure cooling circuit is designed for 50 Hz, increasing average power by factor 2-3 (100-150 Hz) is feasible (under investigation).
- Operation. Currently the processing is conducted at  $\sim 10^{-5}$ - $10^{-4}$  BRD trip rate. With 2 structures running in parallel the after-BRD down time will slow down processing progress. Longer term tests (at a low BRD trip rate) will profit from the higher repetition rate.



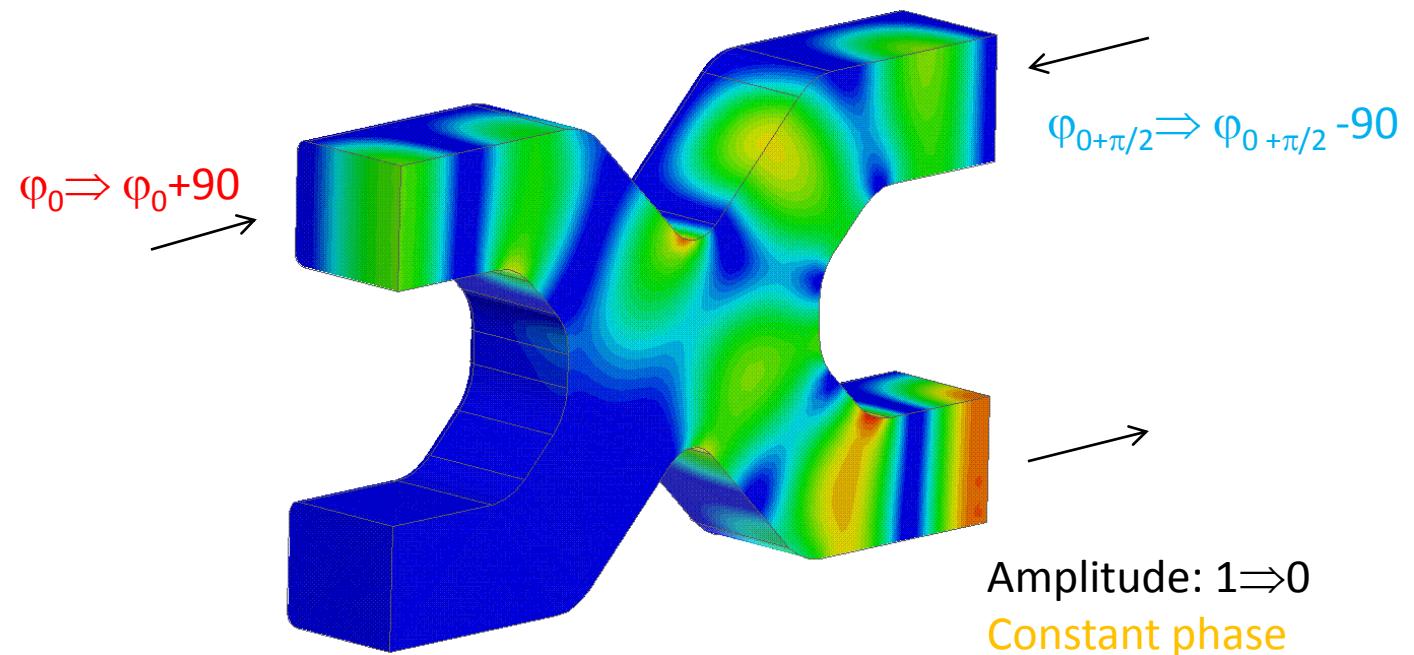
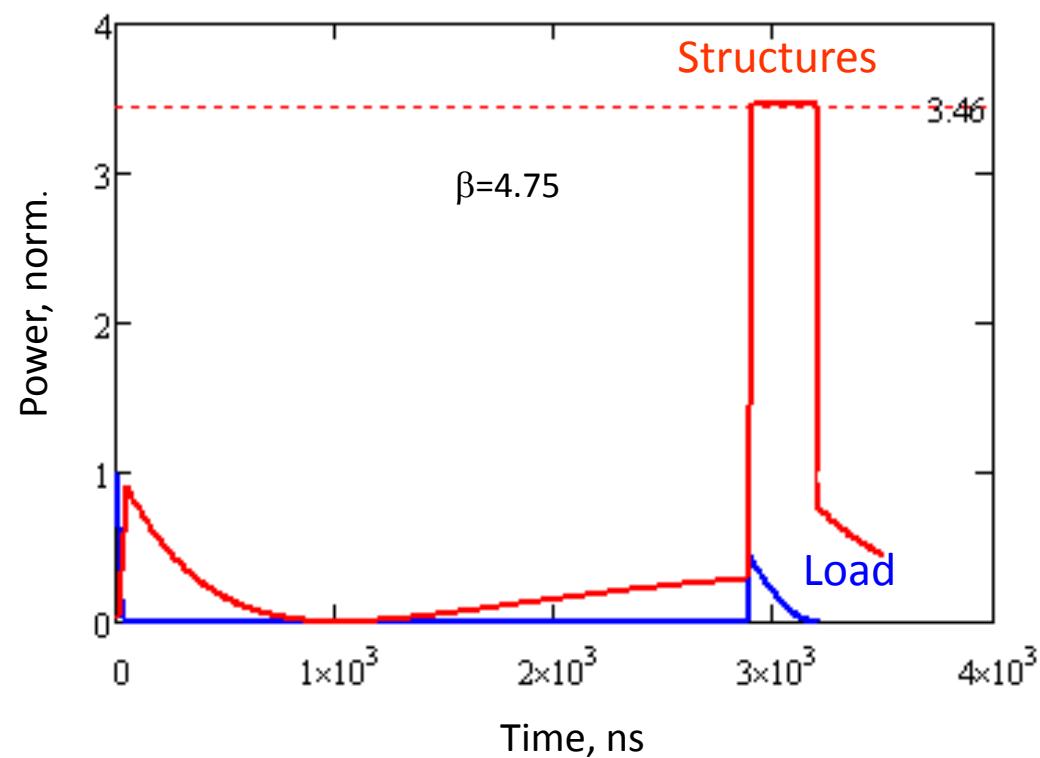
With a single source, the repetition rate and processing time are not correlated linearly

# Can we go even higher (above 100 Hz) in a repetition rate?

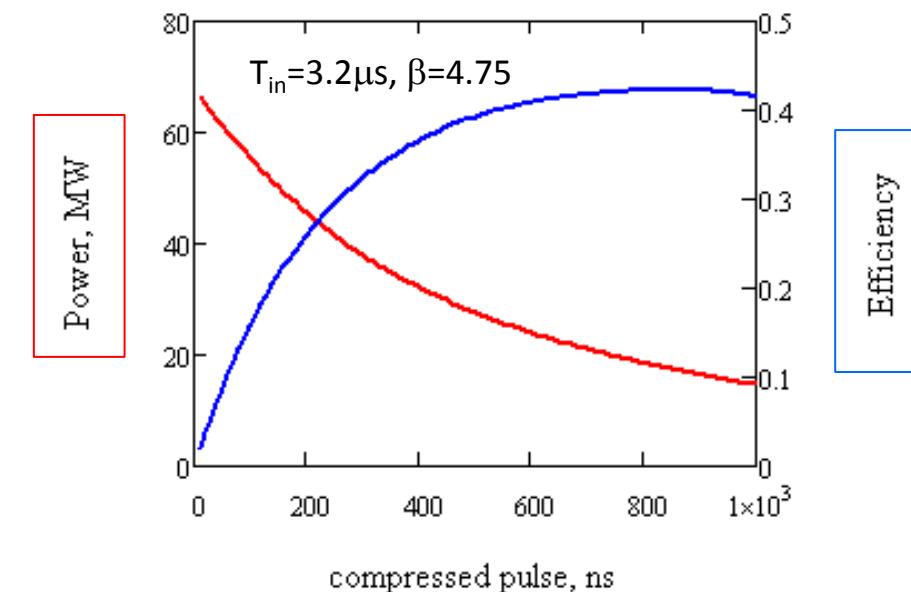
40 MW x few hundred ns, X-band klystrons  
cluster power station + Pulse compressor.



Example:  $T_{in}=3.2\mu s$ ,  $T_{out}=300$  ns  
 $P_{in}=2 \times 5.5$  MW,  $P_{out}=38$  MW

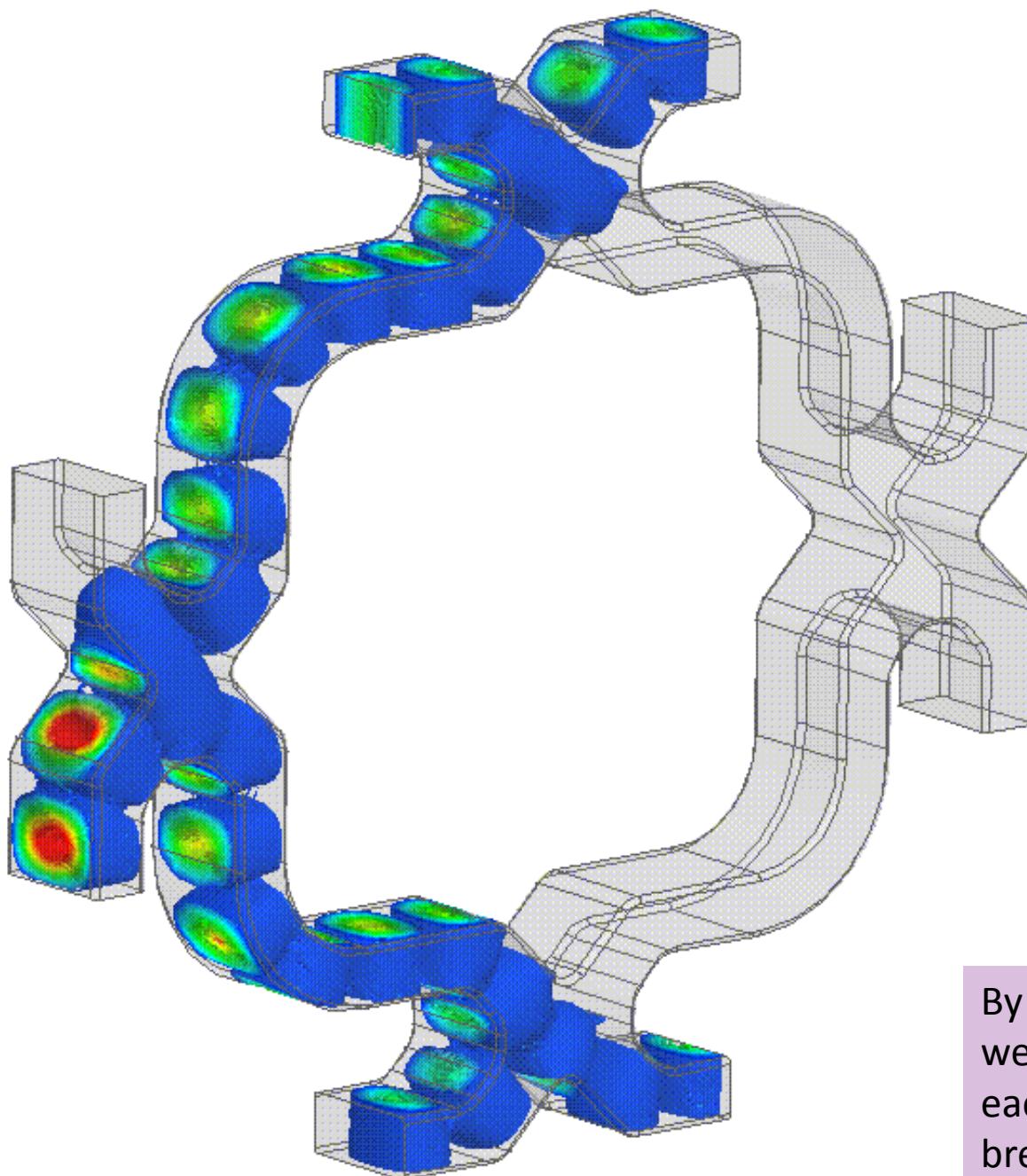


Peak power vs. pulse length

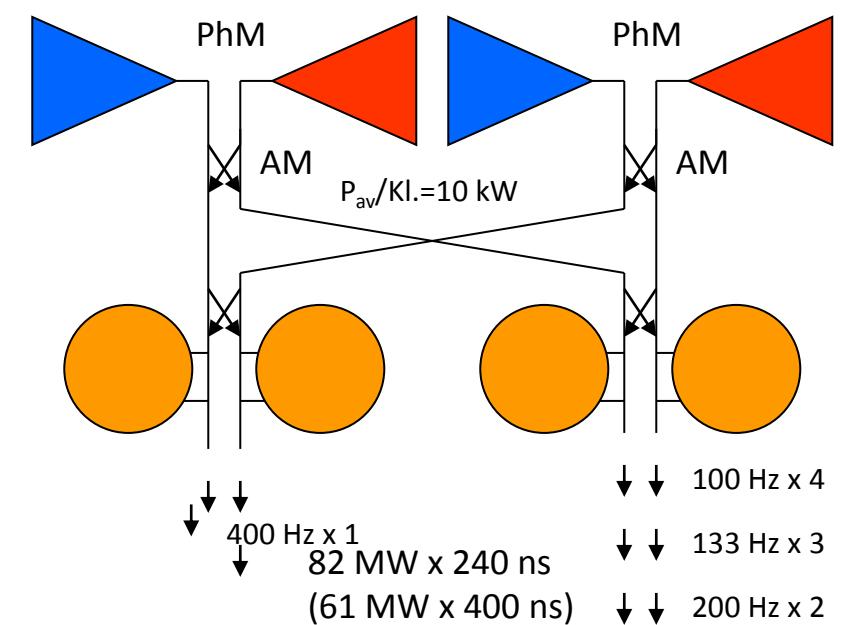


Combining the two stations we get an access to 80 MW peak power **kHz range** test facility!  
Drawback: The efficiency goes down to  $\sim 14\%$  for 240 ns pulses.

## High power 4 port commutation with a phase manipulation

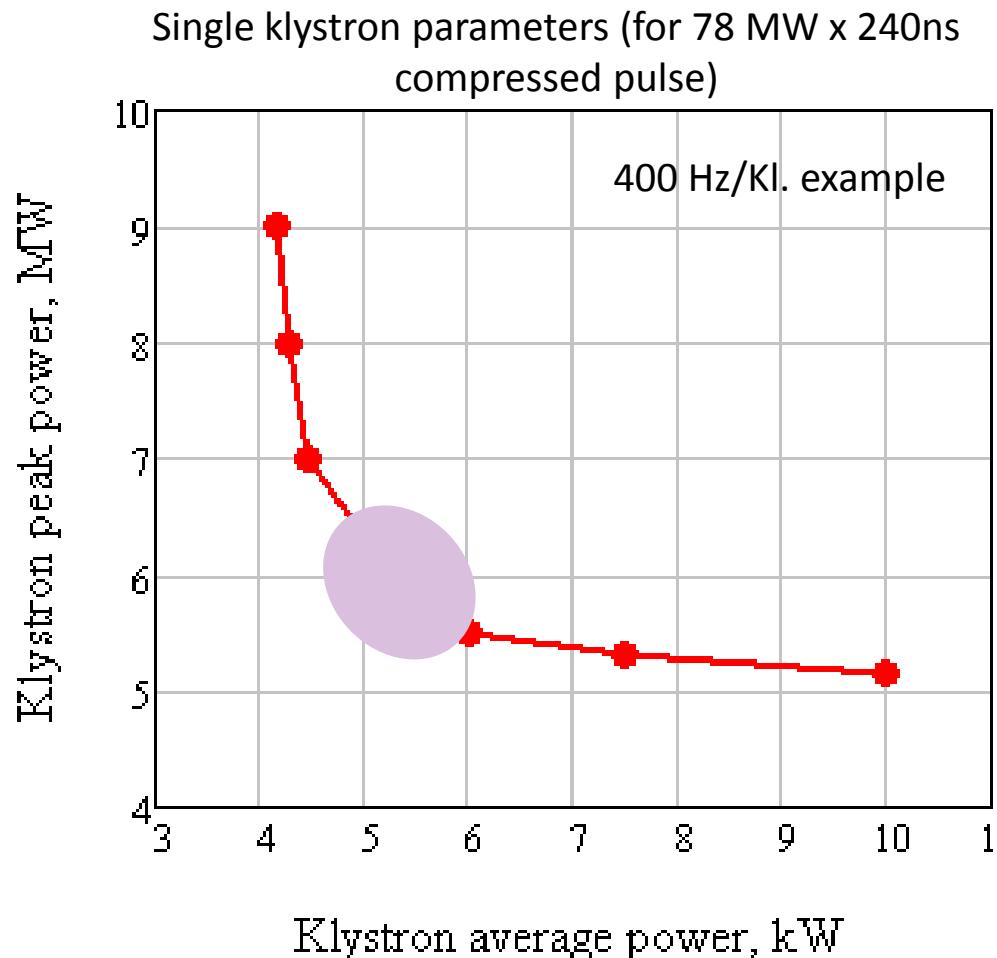
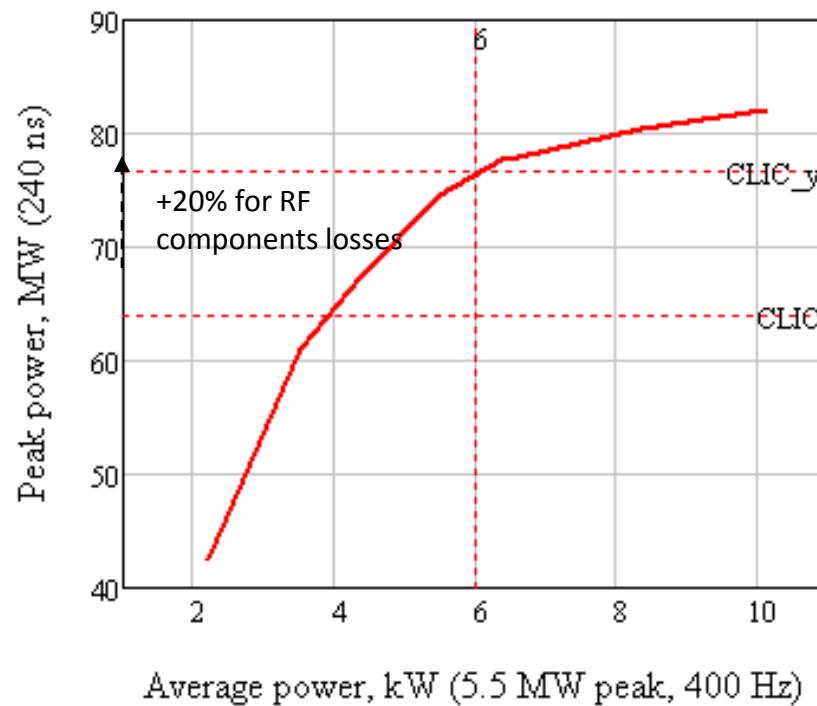


**12 GHz** (5.5 MW x 4.6 μsec x **400 Hz**) x 4

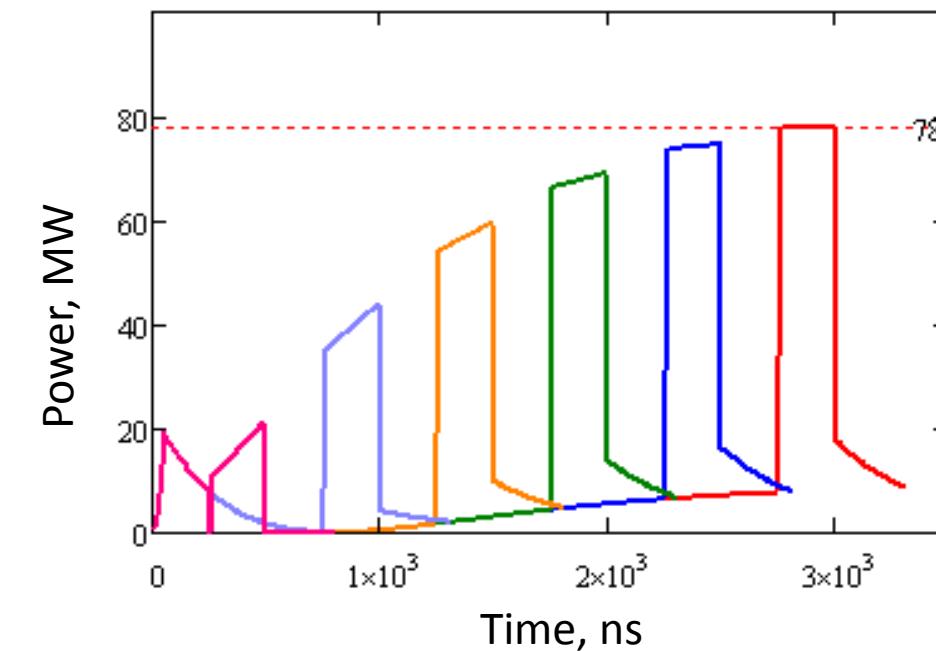


By RF phase manipulation of klystrons pairs ( $0$ - $\pi$ ), we can establish 4 testing slots running at 100 Hz each. In the case of a single/few structure/s breakdown/s, the missing pulse can be sent to any other testing channel, thus maintaining the overall repetition rate available for the tests.

# Single klystron peak and average power issues



➤ 5.5MW-6.5MW peak power klystron looks like an optimal choice to provide efficient generation of the pulses for CLIC accelerating structures testing.



## Operation issues:

After breakdown, the accelerating structure needs to be re-processed. This is normally done by gradual increasing both the peak power and pulse length. In our case it can be done in a simple way by changing only the klystron pulse length without re-programming klystron phase modulation. In a similar way the peak power can be balanced between the channels



The 9.3 GHz version of such a tube is available on the market. At least two companies (CPI and L3 in US) have developed industrial prototypes and Thales (Europe) has a paper design.



The L6145 is a fixed-tuned, cathode-pulsed X-band klystron amplifier for use in high energy linear accelerator systems. Peak output power exceeds 5.0 megawatts at 0.4% duty; average power capability is 20 kilowatts.

DS61450410

## L6145 X-Band Klystron Amplifier

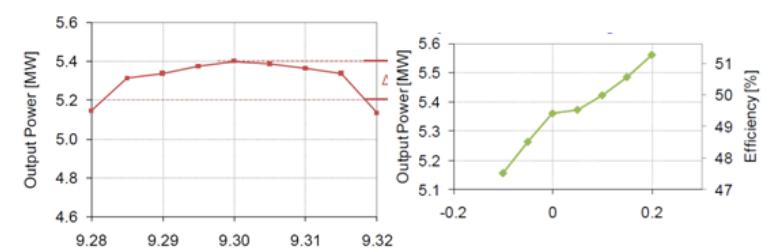
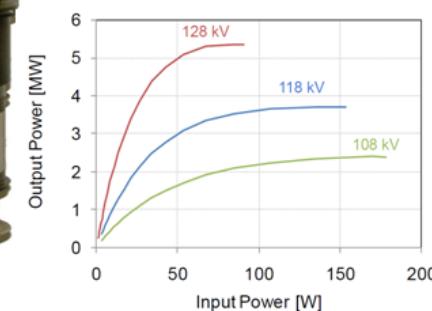


Performance (As specified)	
Frequency (MHz)	9300
Peak Output Power (min, MW)	5.0
Beam Voltage (max, kV)	135
Beam Current (max, A)	86
Drive Power (max, W)	50
Duty (RF, %)	0.4
RF Pulse Width (typical, $\mu$ s)	3.2
Beam Pulse Width (typical, $\mu$ s)	4.0
Heater Voltage ( $V_{rms}$ or Vdc)	7.0
Heater Current (A <sub>rms</sub> or Adc)	21
Ion Pump Voltage (min, kV)	3.0
Solenoid Voltage (max, Vdc)	130
Solenoid Current (Adc)	35±1
Bucking Coil Current (max, Adc)	1.5

Demonstrated:

- Excellent performance demonstrated
  - 5.4 MW peak at 9.3 GHz
  - Operated at 128 kV and 84 A
  - Efficiency of 50 percent
  - Tested to 6 kW average
    - Higher average power testing on hold until we find a suitable water-load

With 3.2 $\mu$ s, 5.4 MW pulses and 6 kW average, The repetition rate was 350 Hz.



IEEE International Vacuum Electronics Conference

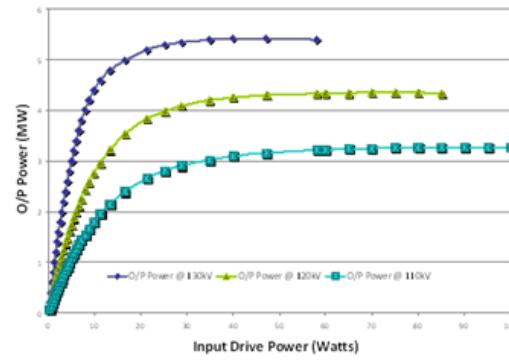
Rome, Italy  
April 28-30, 2009



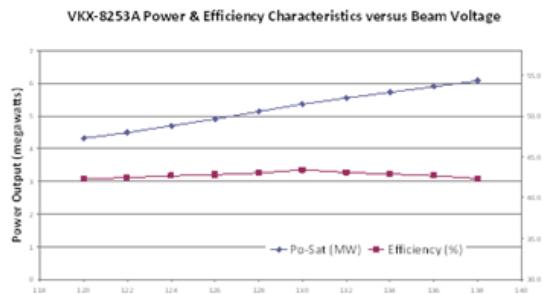
## VKX-8253A



The VKX-8253A is a solenoid focused 9.3 GHz klystron has demonstrated 5.4 MW peak at 18 kW average, and achieved 6 MW peak at 6 kW average. The unit is designed to achieve 20 kW average at 5 MW peak but operation is currently limited by test station availability.



Prototype Operating Parameters		
Item	Value	Units
Beam Voltage	130	kV
Beam Current	95	A
Frequency	9.3	GHz
Peak Power	5.4	MW
Ave. Power	18	KW
Sat. Gain	50.9	dB
Efficiency	43.7	%
Duty	0.34	%

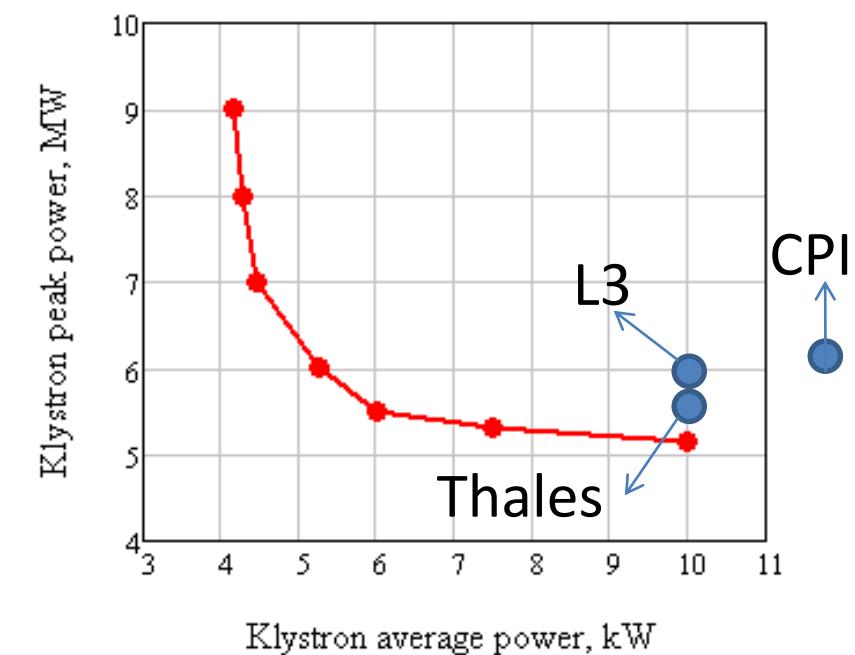


The values listed above represent specified limits for the product and are subject to change. The data should be used for basic information only. Formal, controlled specifications may be obtained from CPI for use in equipment design.

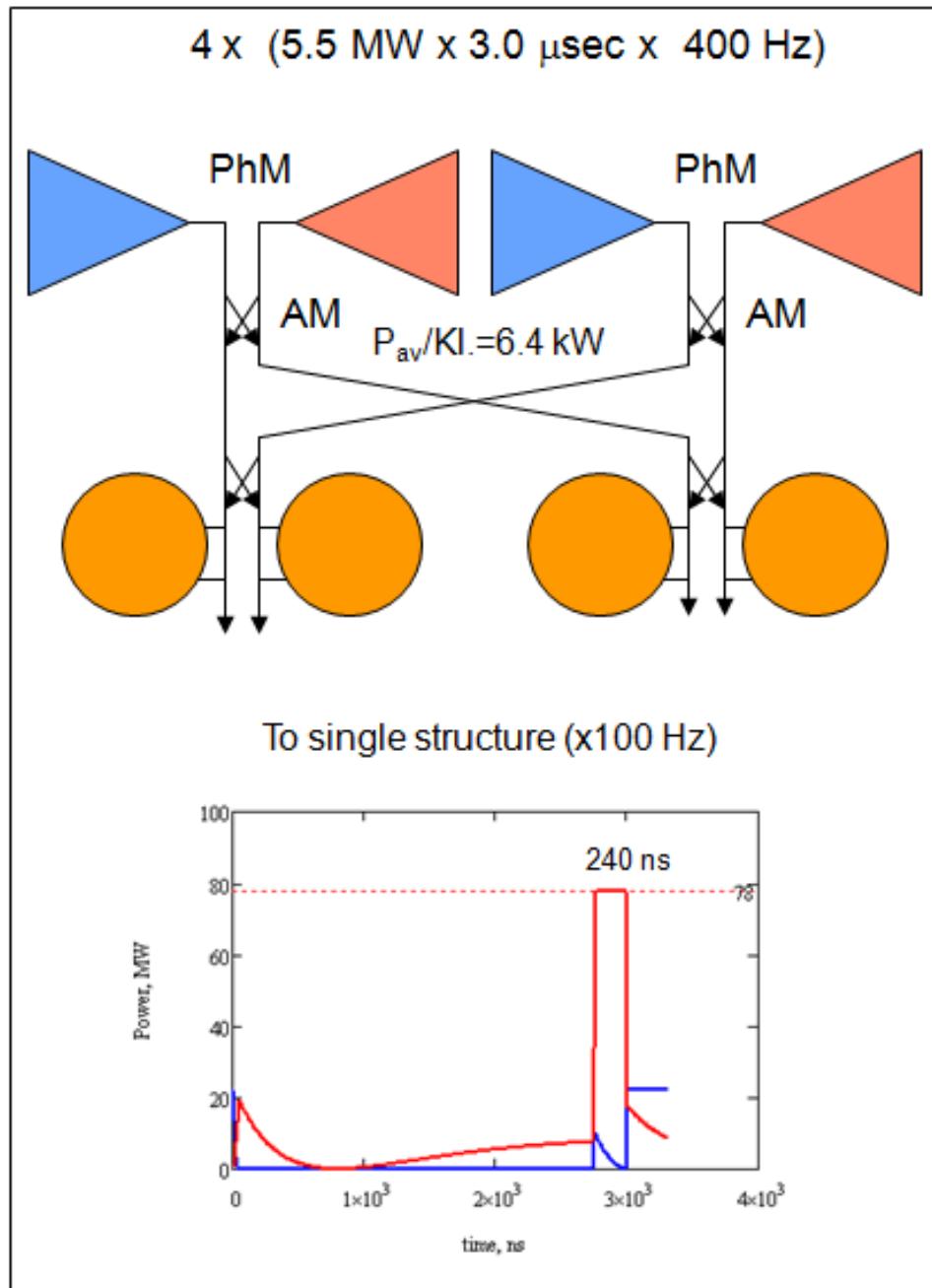
ISO 9001 Certified Quality System

For information on this and other CPI products visit our webpage at [www.cpi.com](http://www.cpi.com), or contact CPI MPP Division, 607 Hansen Way, Palo Alto, CA 94303 Telephone: 1 (800) 414-8823 FAX: 1 (650) 856-0705 email: [marketing@cpi.com](mailto:marketing@cpi.com)

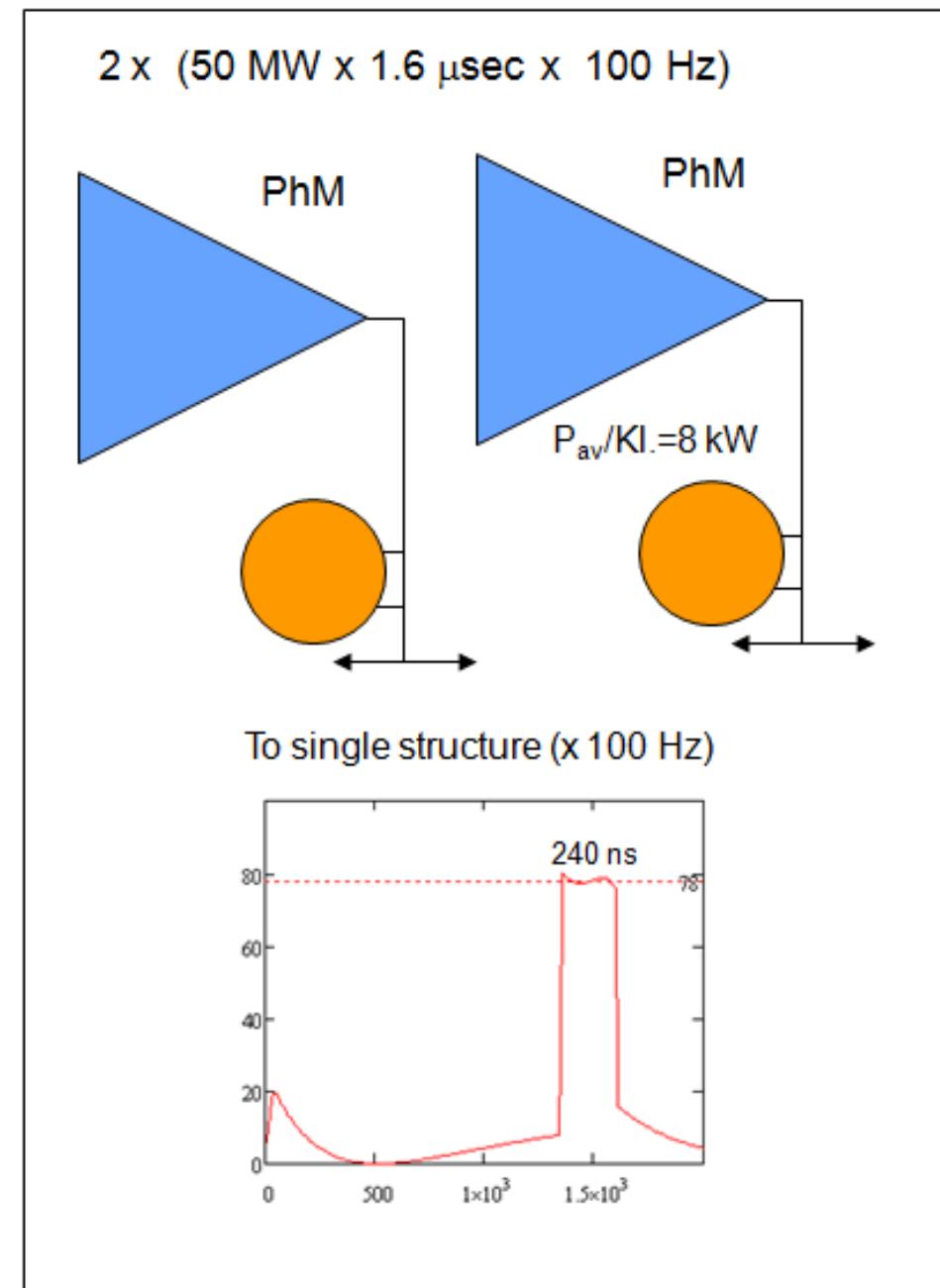
All these companies were contacted and expressed their interests in scaling the existing 9.3 GHz devices to 12 GHz



# High peak power klystron vs. medium power klystrons cluster. Performance issues.

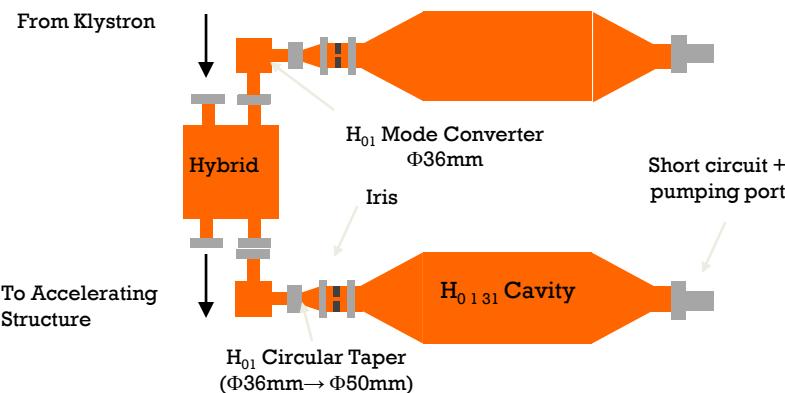
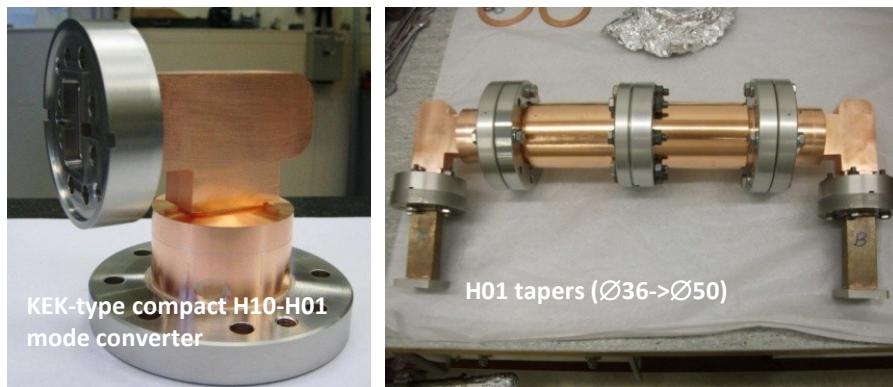
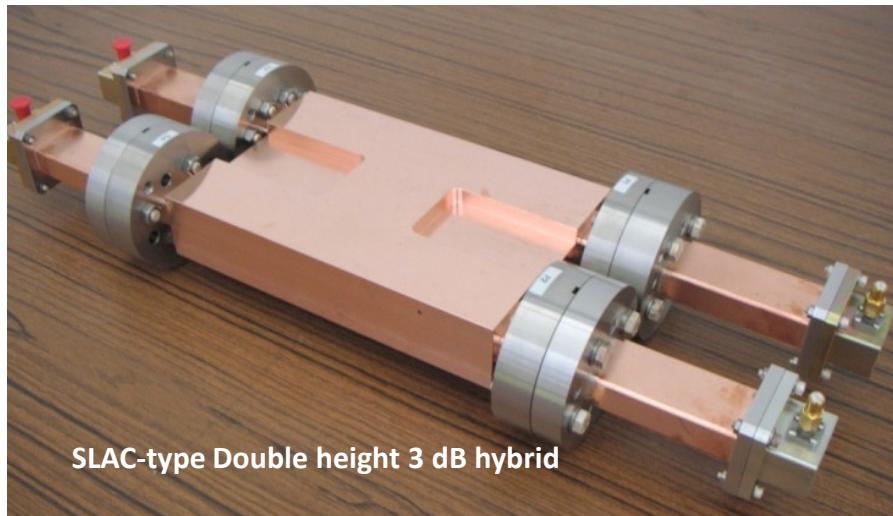


Equivalent in terms of  
delivered number of  
pulses

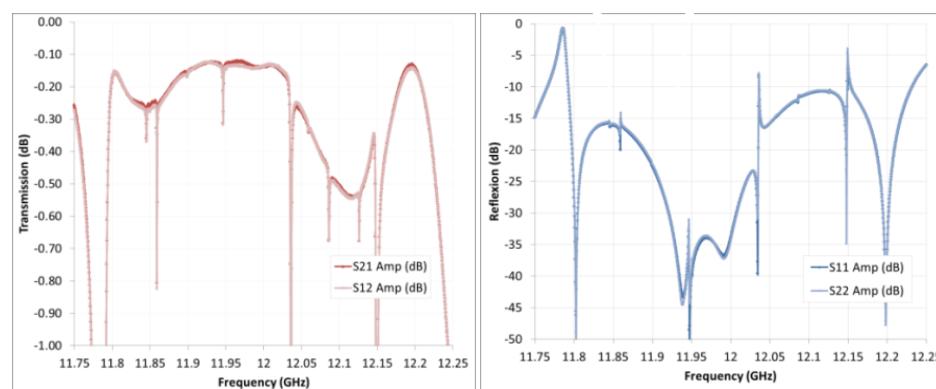
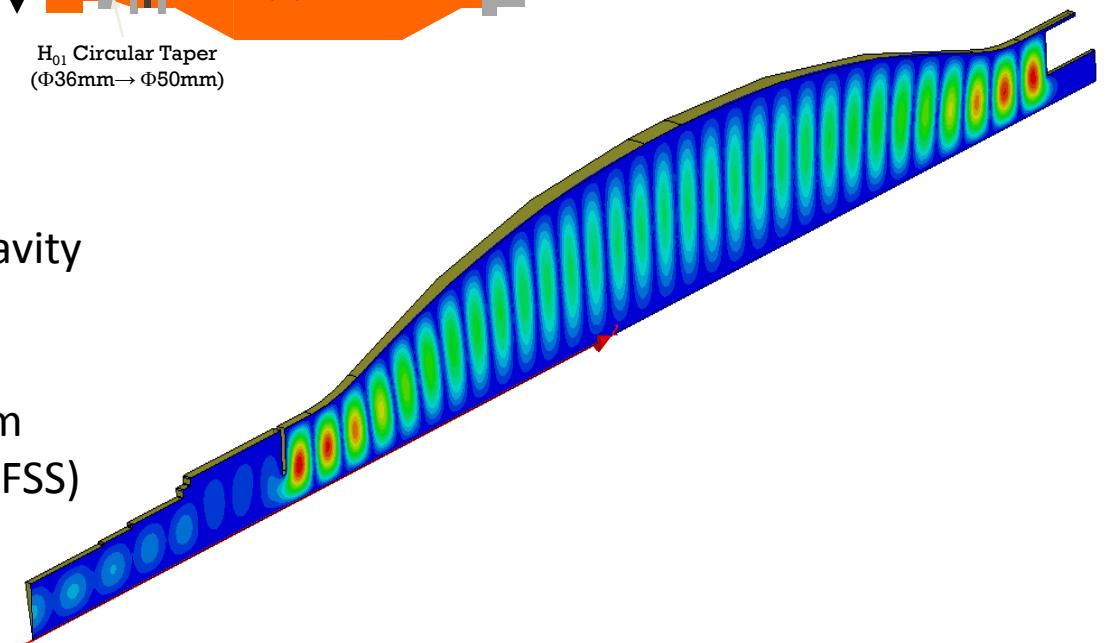


# Compact SLED-type X-band pulse compressor.

## Design & components by F. Peauger, CEA.



H01M 'rugby' cavity  
Mode:  $H_{0,1,31}$   
Length: 420mm  
Max.  $\varnothing$ : 110 mm  
 $Q_0$ :  $1.82 \times 10^5$  (HFSS)



These components were designed and fabricated by CEA as a French in-kind contribution to the 12 GHz klystron station waveguide network at CERN

- The mode converters are used to pre-fabricate  $H_{01}$  mode in a circular waveguide ( $\varnothing 50$  m). The coupling iris and tuning piston are also placed in the same diameter to avoid diffraction coupling to the modes with higher radial number ( $H_{0,N>1,M}$ ).
- The cavity shape is optimized to provide required  $Q_0$  ( $1.8 \times 10^5$ ). The internal tapers are designed to minimize modes conversions of the operating mode.
- The fixed tuning pistons will be used as a separate (not the part of vacuum system) pieces to balance the cavities frequencies. Final frequency tuning will be done with the cooling water temperature control.

# Other applications

**ZFEL**  
**een compacte zachteröntgenlaser**

Golflengte: 0.8 - 20 nm      Herhaalfrequentie: **1 kHz**      Pulsduur: 1-50 fs

Hoge puls tot puls stabiliteit door hogere harmonische seeding  
Compact (~100 m) door X band gebaseerde technologie

Kernfysisch Versneller Instituut en Zernike Institute for Advanced Materials:  
Bestaande expertisecentra voor gebruikersexperimenten  
Synergie van wetenschap, technologieontwikkeling, sample preparatie, analyse, ...

**Seeden en röntgenoptica**

**Elektronenbron**

**Wetenschap**

**X-band linac module**

**Undulator**

**Versneller**

**Load**

**Accelerating structure**

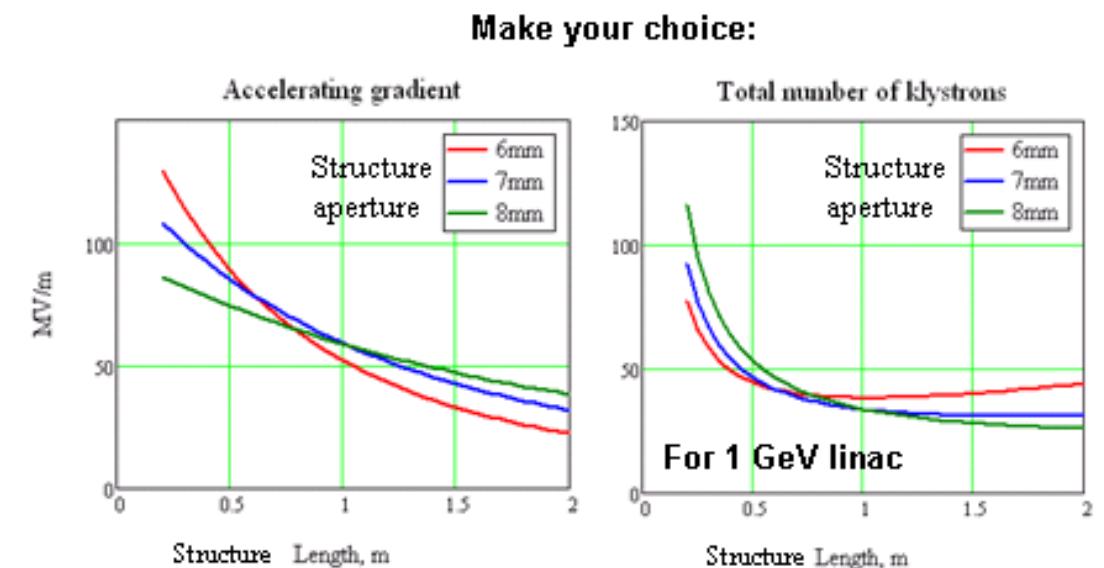
**... neem contact op met het team:**

**KVI**      University of Groningen  
Zernike Institute for Advanced Materials

**Rijksuniversiteit Groningen**

**Prof. dr. Ir. Ronald J. Hulshoff (KVI)  
Prof. dr. Ir. Paul van Loon (ZIAM)  
tel: 050 500 1727**

The new collaboration between CLIC/CERN and KVI/GRONINGEN (Netherlands) has been recently established. The subject is the development of high gradient electron linac based on CLIC (12 GHz) accelerating structure technology capable to operate at ~1 kHz repetition rate.



The moderate peak power klystron cluster plus pulse compressor is the most economic way to deliver high peak RF power and high repetition rate.