THALES

THALES RF sources for accelerator Recent developments

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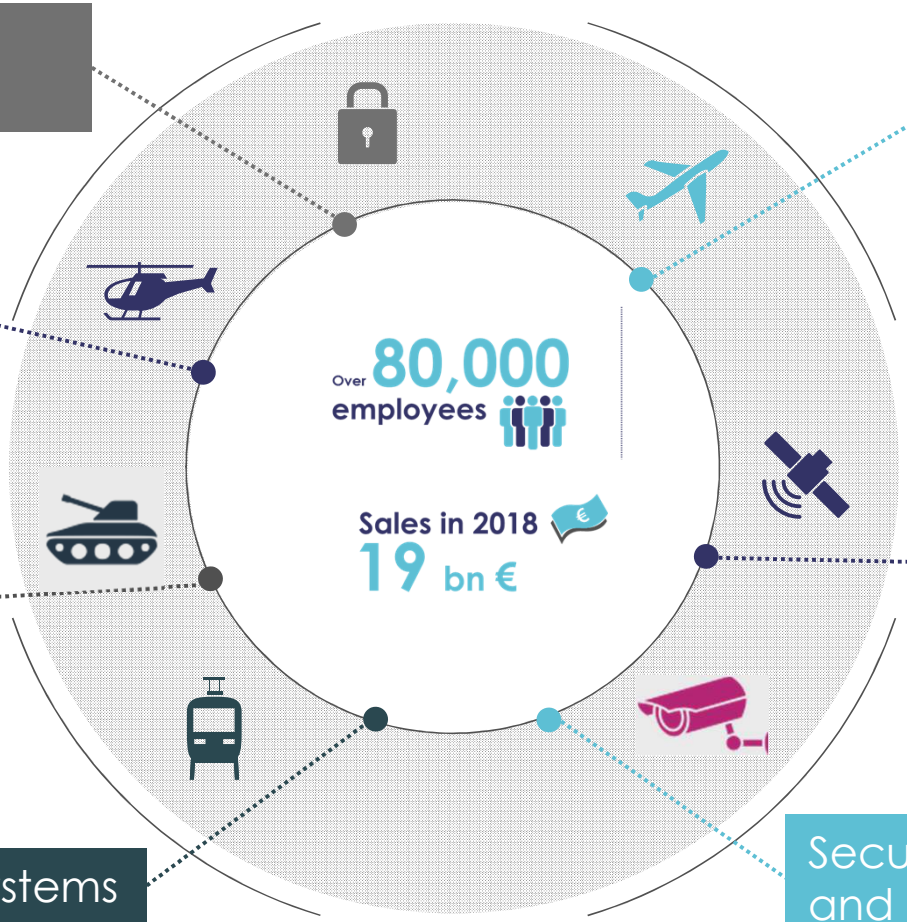
Compact Light 2nd Midterm Meeting
UH/HIP, Helsinki, 01 – 04 July 2019

Outline

- THALES Microwave & Imaging Sub-Systems
- High power klystrons for injectors and linacs
- High efficiency tube developments (< 1.3GHz)

Thales AVS MIS Business Line within Thales Group



Digital Identity and Security

Land and Air Systems

Defence Mission Systems

Ground Transportation Systems

Avionics

Flight Avionics
In-Flight Experience
Electrical Systems
Training & Simulation
MICROWAVE & IMAGING SUB-SYSTEMS (MIS)

Space

Secure Communications and Information Systems

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Thales AVS MIS Business Line

Design and production of electron devices and RF amplifiers (tube based)

- Traveling wave tubes, klystrons, magnetrons, grid tubes, gyrotrons, space & defence amplifiers, ion thrusters
- Also RF components as windows, couplers, loads

Conventional & digital imaging for radiology systems,

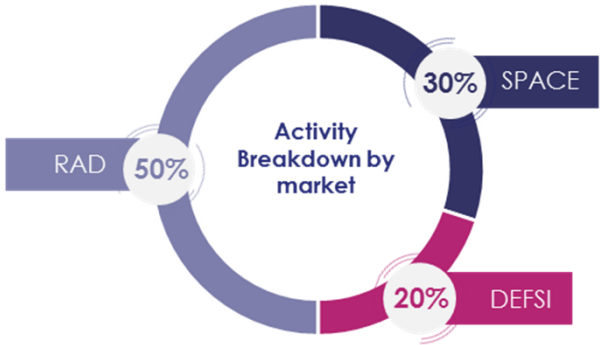
- Design and production of flat panel X-rays detectors
- Production of conventional tubes (IIR)
- Imaging software

2 600 employees

100,000 m² industrial surface, including 9,000 m² clean rooms

8 industrial sites (production, R&D)

12,000 product references

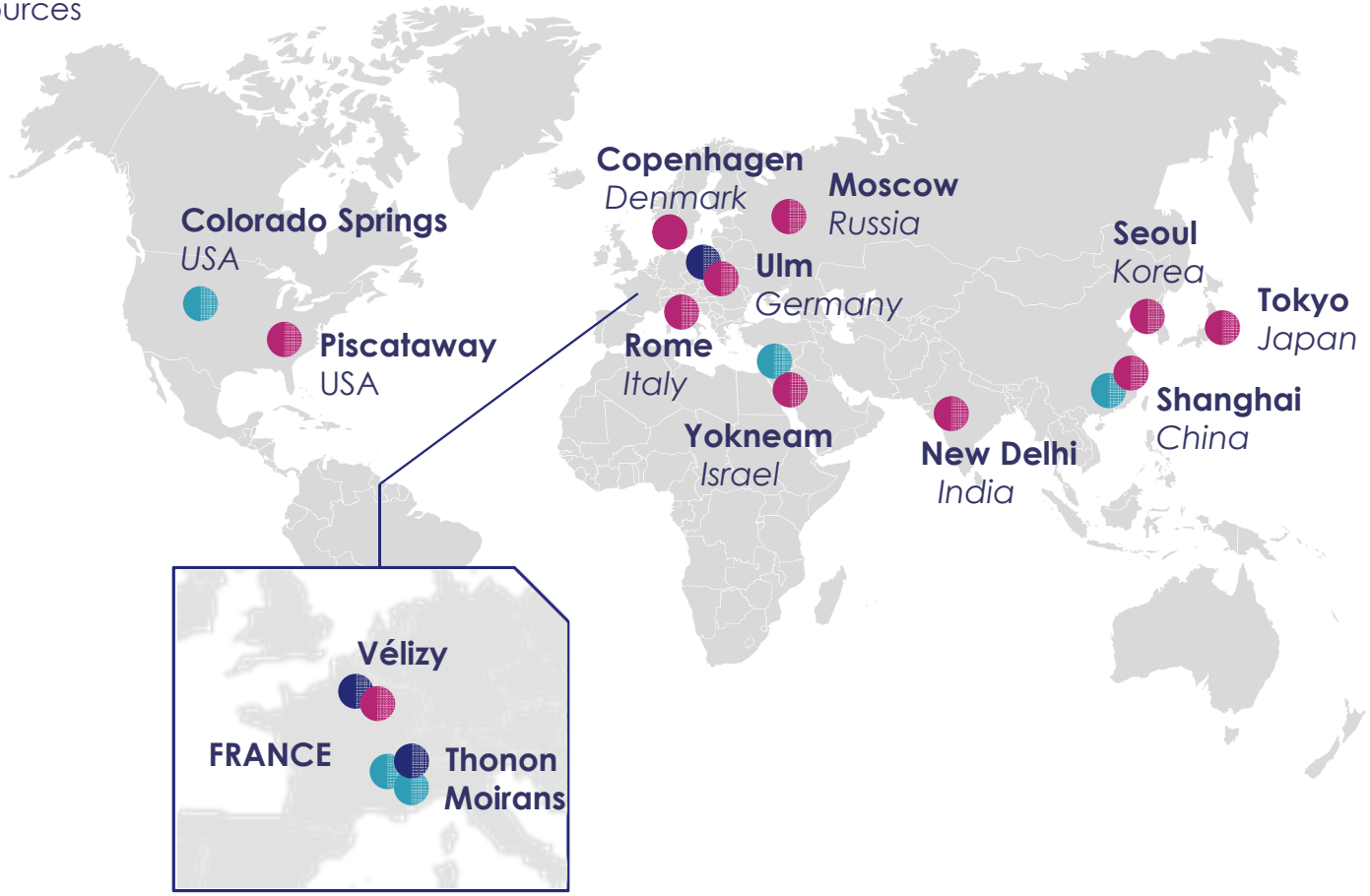


Thales MIS global presence

RF & Microwave sources
Production centres

Radiology
Production centres

Sales offices



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High power S-Band short pulse klystrons for injectors and linacs

TH2128 & TH2100 klystrons (2856 & 2998 MHz)

- 30 MW--- 60MW / 5µs ---1.5µs
- Average power up to 20kW
- 305kV x 350A (30MW) --- 350kV x 410A (60MW)
- Vacuum or SF6 WR284 single output
- More than 100 tubes manufactured
- Lifetime > 40.000 hrs
- Electromagnet and X-ray shieding

TH2132 & TH2155 klystrons (2998 MHz, 2 outputs)

- 45MW / 4.5µs
- up to 50kW average
- 2 x SF6 WR284 outputs

TH 2128 & TH 2100
60 MW peak/20 kW average in S-band.

TH2100 klystron at PSI

TH2132A klystron at ELETTRA

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High power L-Band long pulse multibeam klystron for SC linacs

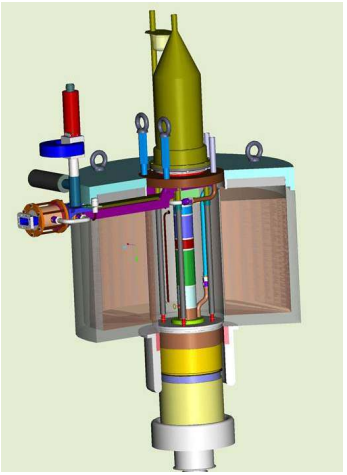
TH1801A and TH1802 (Multibeam Technology)

- RF Power = up to 10MW (pulse width = 1.500 ms)
- 7 beams (0.5 µperv), 6 cavities
- Electrical characteristics = 116kV / 136A
- Efficiency = higher than 63%
- Can be delivered in vertical position with a separate focusing magnet or in horizontal position, as a turn-key solution with built-in shielding and magnet.
- 22 positions installed on EU XFEL at DESY

Development of X-band high power klystrons

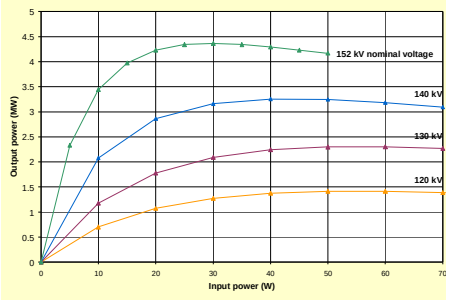
Paper study of a X-Band Klystron for Medical and Cargo Screening applications performed in 2012

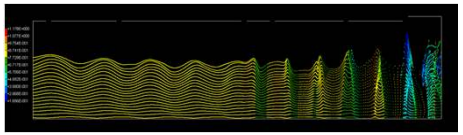
- 9.3GHz 4MW 5µs 200 Hz 152 kV 59.4A 50%
- 6 cavities structure including one operating on harmonic 2
- cathode current density J< 5.8A/cm²
- noseless single cell output cavity
- standard pill box RF window



No on-going development on C/X-Band high power klystrons

- market covered by 3 to 4 manufacturers with products satisfying the demand
- willingness of Thales to follow but no investment capacity to adress this domain given the quantities; no return on investment if self funded
- transfert of technology to be considered in case of large quantities and limited production capacities of manufacturers

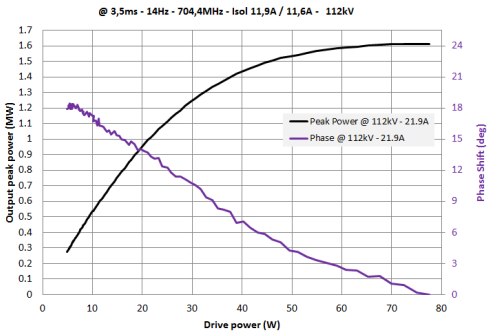


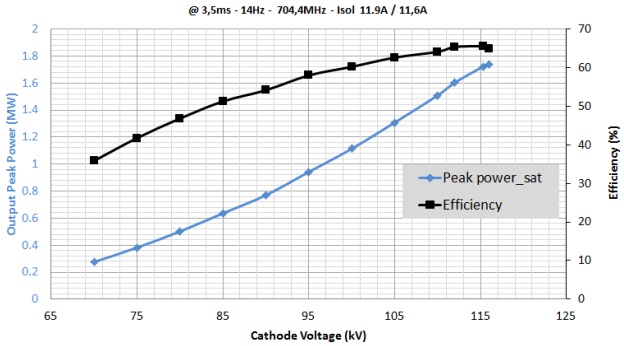


High power UHF long pulse klystron for proton linacs

1.5 MW Peak, 704 MHz, long pulse klystron (TH2180)

- diode gun , low perveance beam (0.6 µerv)
- standard 6 cavities structure with 2nd harmonic cavity in 3rd position, 1.5m long, 69% predicted efficiency with internal code Klys2D
- pill box window (WR1150)
- built-in electromagnet and oil tank
- measured 1.6MW output power with 65 % efficiency at 112kV 21.9A 3.6ms
- selected for ESS high beta linac sections





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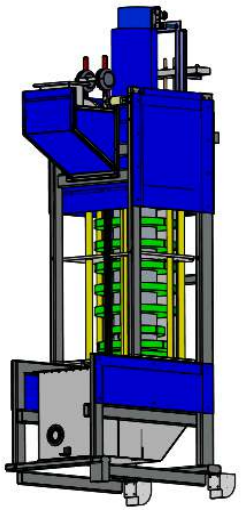

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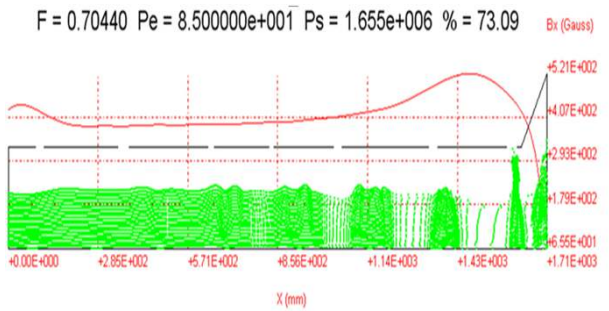
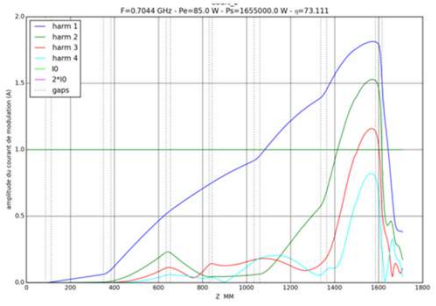
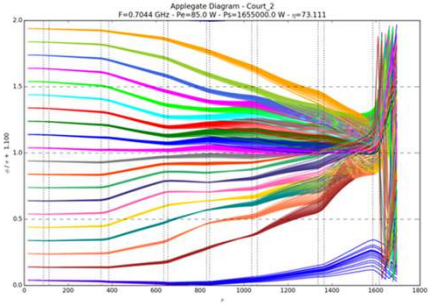
Towards a higher efficiency klystron (TH2180)

Design (paper study) of a CSM structure including an additional 3rd harmonic cavity in 4th position

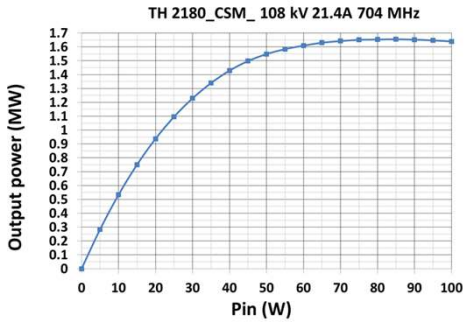
- Adding a 3rd harmonic cavity increases the predicted efficiency by 3 to 4% (Magic & Klys 2D); 68-70% achievable
- Implementation of the 3rd harmonic cavity needs to be validated on a prototype
- Next batch of Thales klystrons for ESS will be with standard structure

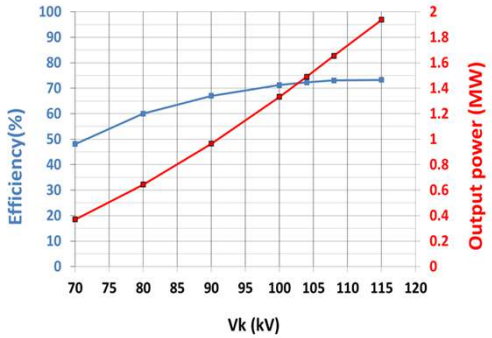


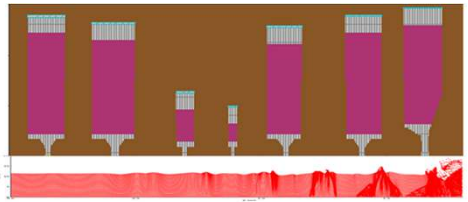




Simulation of the CSM structure with magnetic field : 1.65MW 73.1% 108kV 21.4A 42.9dB







CSM structure 1.5m long 1.6MW 72% 108kV 21.4A 43.5dB

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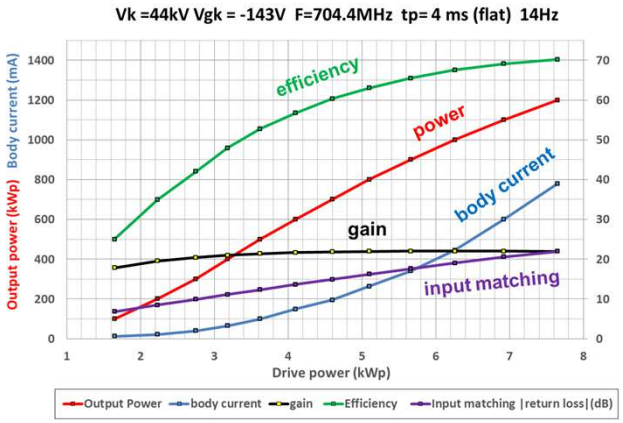
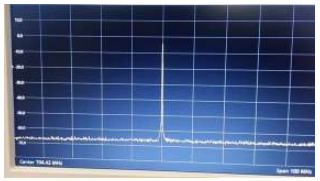
High efficiency 1.2 MW, 704 MHz, long pulse Multi-Beam IOT

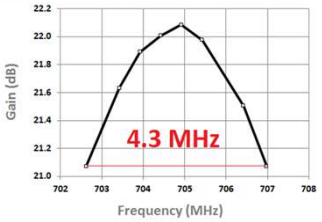
Solution for Megawatt class output power at beam voltage < 50kV and efficiency > 70%

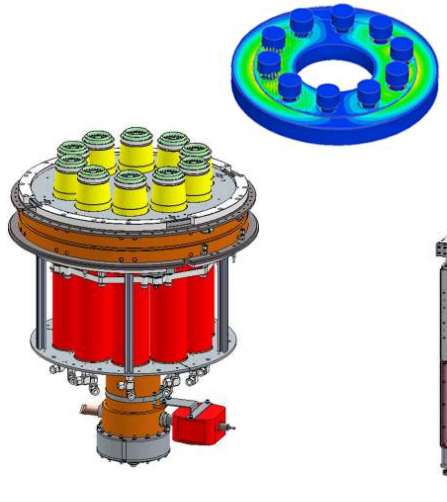
- Demonstrator developed in consortium with CPI for ESS
- 10 gridded guns, solenoid focusing, coaxial cavity, coaxial window, coax-to-WR1150 WG , single drive
- Achieved up to 1.35MW at 45kV with 70% efficiency (including interpulse idle current)
- No instabilities

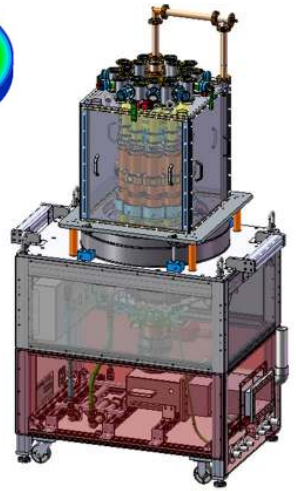


Parameters	Performances
Frequency	704.42 MHz
Peak power	1.2 MW
Average power	77.3 kW
RF pulse width (flat top)	4 ms
Beam voltage	44 kV
Beam current (total)	38.6 A
Efficiency	70.2 %
Gain	22 dB
Bandwidth (-1dB)	4.3 MHz
Grid bias voltage	-143 V
Body current	780 mA
Idle current (total)	20 mA
Input return loss	-21.9 dB









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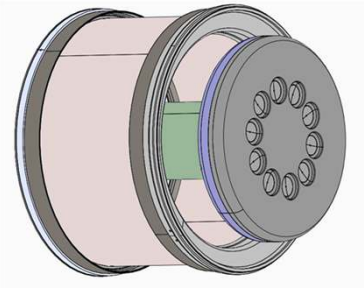
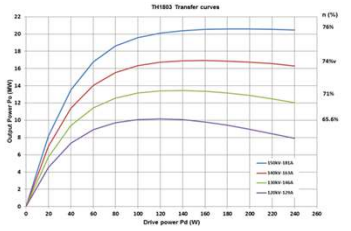
High efficiency 20 MW , 1GHz Multi-Beam Klystron

Solution for multi megawatt class output power at beam voltage < 150kV and efficiency > 70%

- Prototype developed for CERN (CLIC drive beam)
- 10 x low perveance beams (0.35 µperv)
- 6 x coaxial ring cavities, including one 2nd harmonic
- Tested up to 21MW at 146.5kVx191A (150µs) with 73% eff.
- Limited average power due to beam loss
- Limited operating domain due to RF instabilities and beam losses in the output cavity (max 10 Hz rep rate)
- Large (30%) power asymmetry between output ports



Low cathode's current density < 3 A/cm²
Electrical field in gun's region < 7 kV/mm²
Beam focused at 2 to 2,4 Brillouin field



20.6MW predicted with 76% efficiency at 150 kV x 181 A

Measured power curve at 146.5kV x191.2A 150µs - 20.6MW 73.5% at saturation – instability below saturation

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High efficiency 400MHz 300kW CW klystron

Total 16 THALES TH2167 klystrons as part of the LHC RF system

- TH2167 klystron saturated output power limited to 300kW CW

High Luminosity LHC upgrade will require more RF power

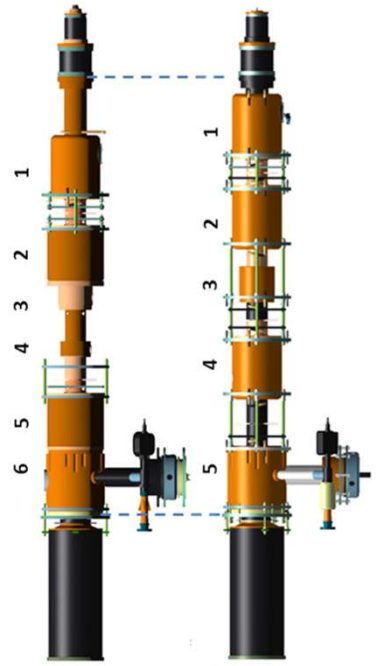
- Need to improve the beam wave interaction efficiency to increase power up to 350 kW and to preserve the existing power supplies
- Plug-in klystron system replacement and re-use of sub-assemblies

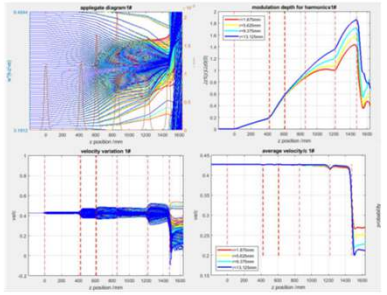
Replace the existing five cavities structure by a high efficiency structure designed by CERN

- CSM (Core oscillation Method) structure with 6 cavities including a second harmonic cavity in 3rd position and a third harmonic cavity in 4th position
- Predicted power is 345 kW at 54kV 9A with and a gain of 36.5 dB and 71% efficiency, 9 points (%) more than the initial structure

On going discussion with CERN to commit into a development collaboration

Picture courtesy of CERN





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THANK YOU FOR YOUR ATTENTION

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