IFAST 3rd Annual meeting, April 2024

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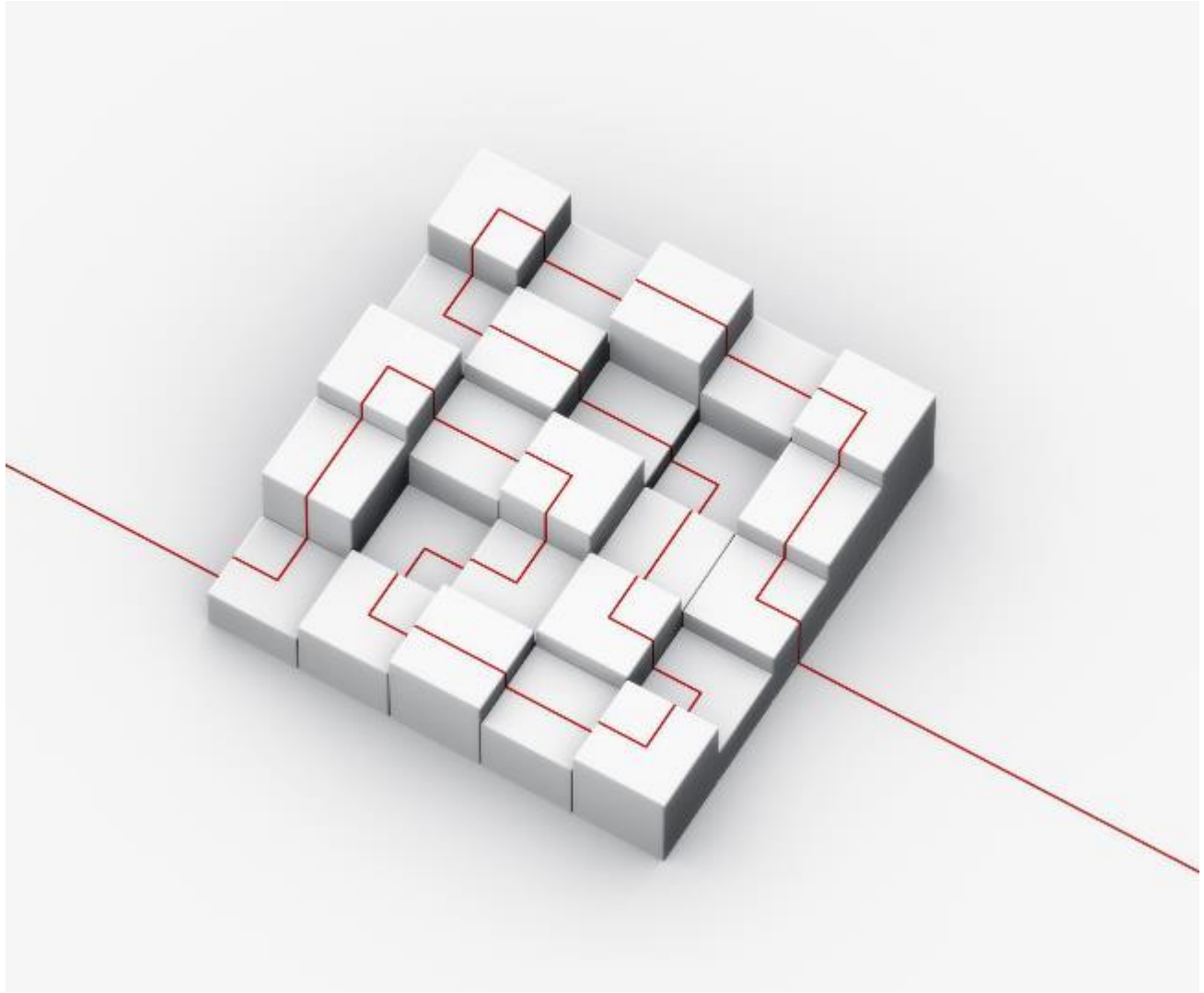
OUTLINE

Reminder at the aim and objectives. HL-LHC needs

Progress report on the design and construction

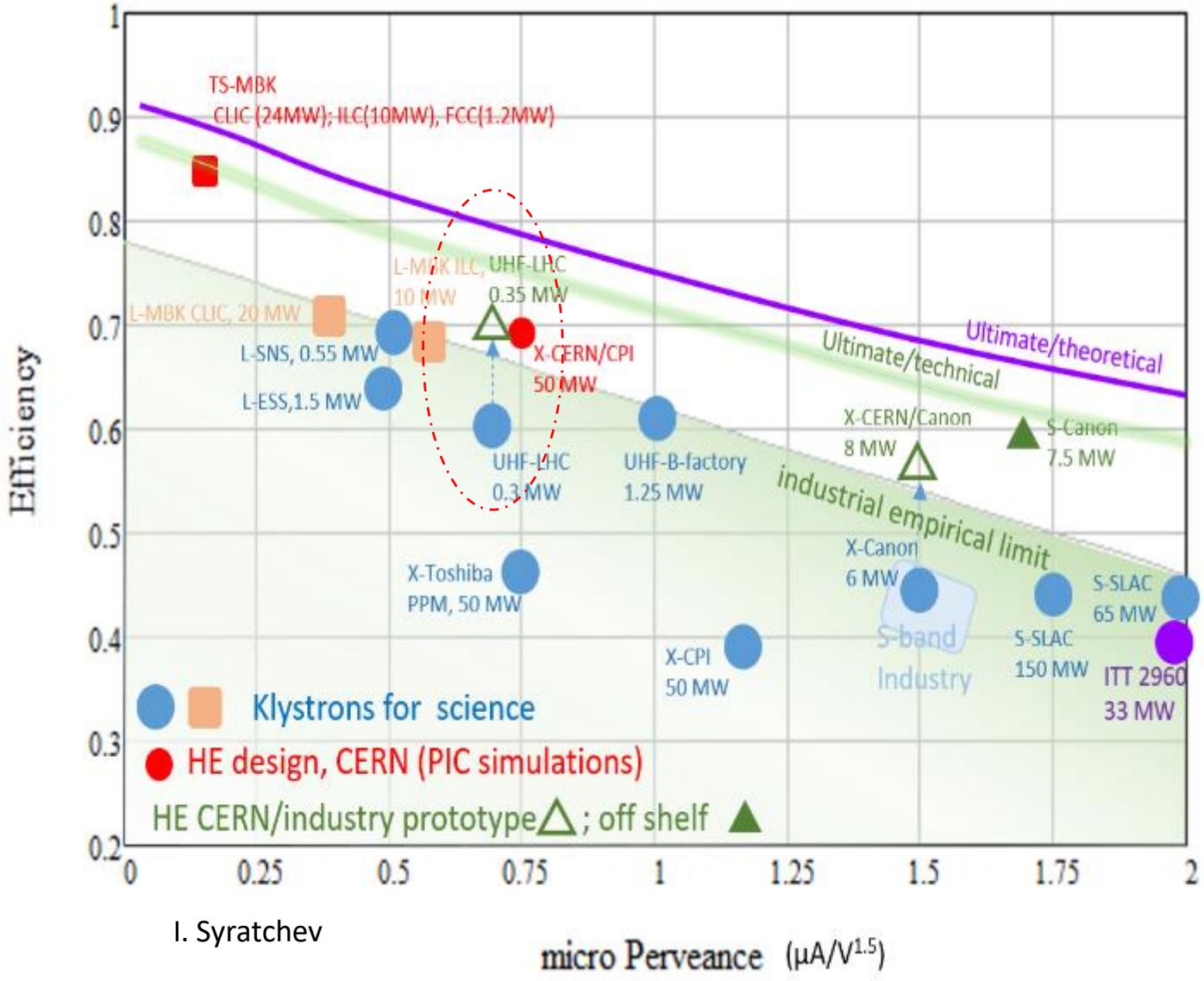
Schedule and next steps

Conclusions



High efficiency klystrons?

- Klystrons in the market limited by an empirical dependence to perveance
- Major CERN involvement on higher efficiency klystrons since 2017 led by I. Syratchev
- New design rules for higher efficiency validated by powerful simulations (KLYC)
- Industrial prototypes are being manufactured around the world



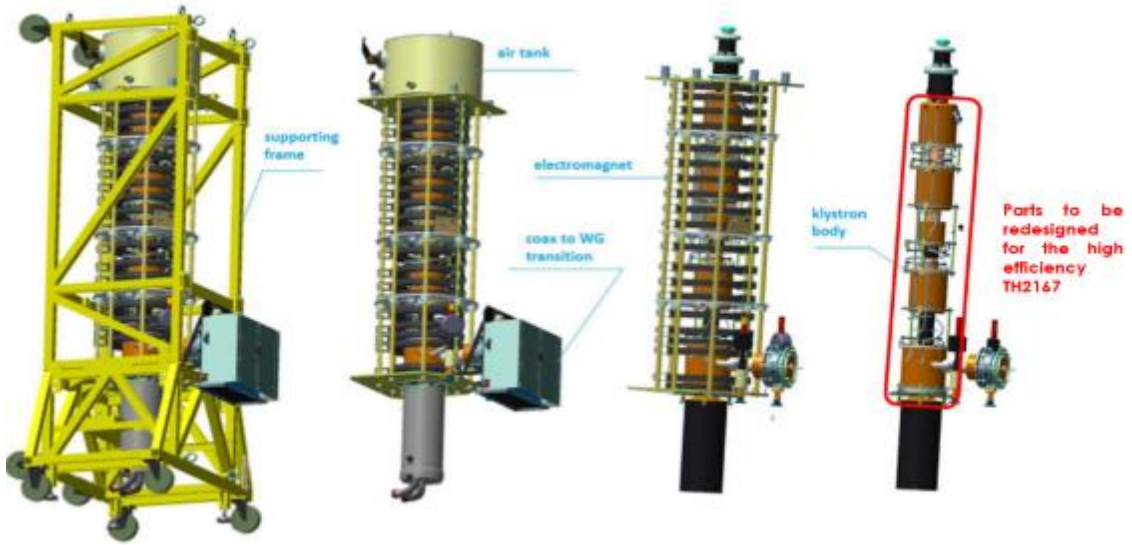
I. Syratchev

Current LHC klystrons

- Total 16+14 THALES TH2167 klystrons
  - 300kW, CW saturated output power at 58kV 8.4A (62% efficiency)
  - Presently operated at ~220kW (-1.5dB below saturation)
- High Luminosity LHC upgrade will require more RF power
- At least 350 kW saturated output RF power per klystron
- At an operating point compatible with the existing power supplies (~58 kV x 9A)
- Need to increase the klystron efficiency to 67% min.

Objective of I.FAST WP 11.2

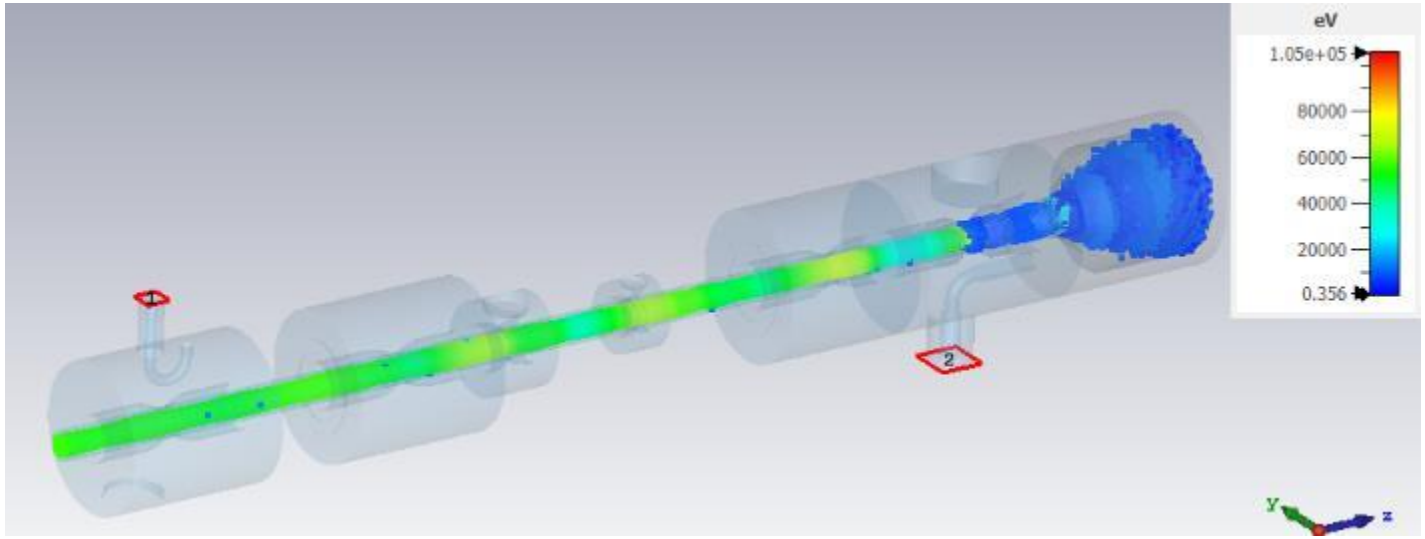
- Design and build an industrial prototype of the LHC klystron reaching ~70% efficiency, in collaboration with THALES.
- In order to control the costs, the choice was made to retrofit the existing LHC klystrons, TH2167, with the aim of reusing some components (e.g. solenoid).
- Kick off meeting in Sept 2021

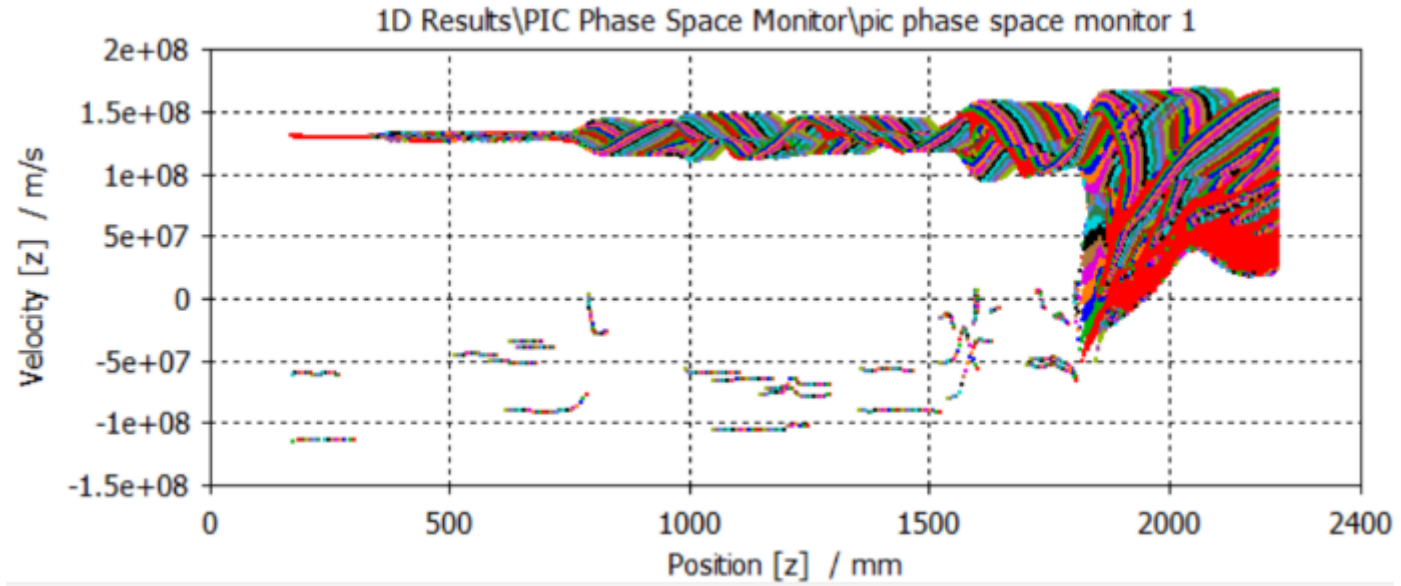


Design and simulations

- Twelve months effort by CERN and THALES teams.
- Final design converged end 2022
  - Saturation at 70 W,
  - Voltage 57.7 kV
  - beam current 9A
  - reduced magnetic field on last two coils

  RF Efficiency = 69.84%
- PIC simulations verified by THALES





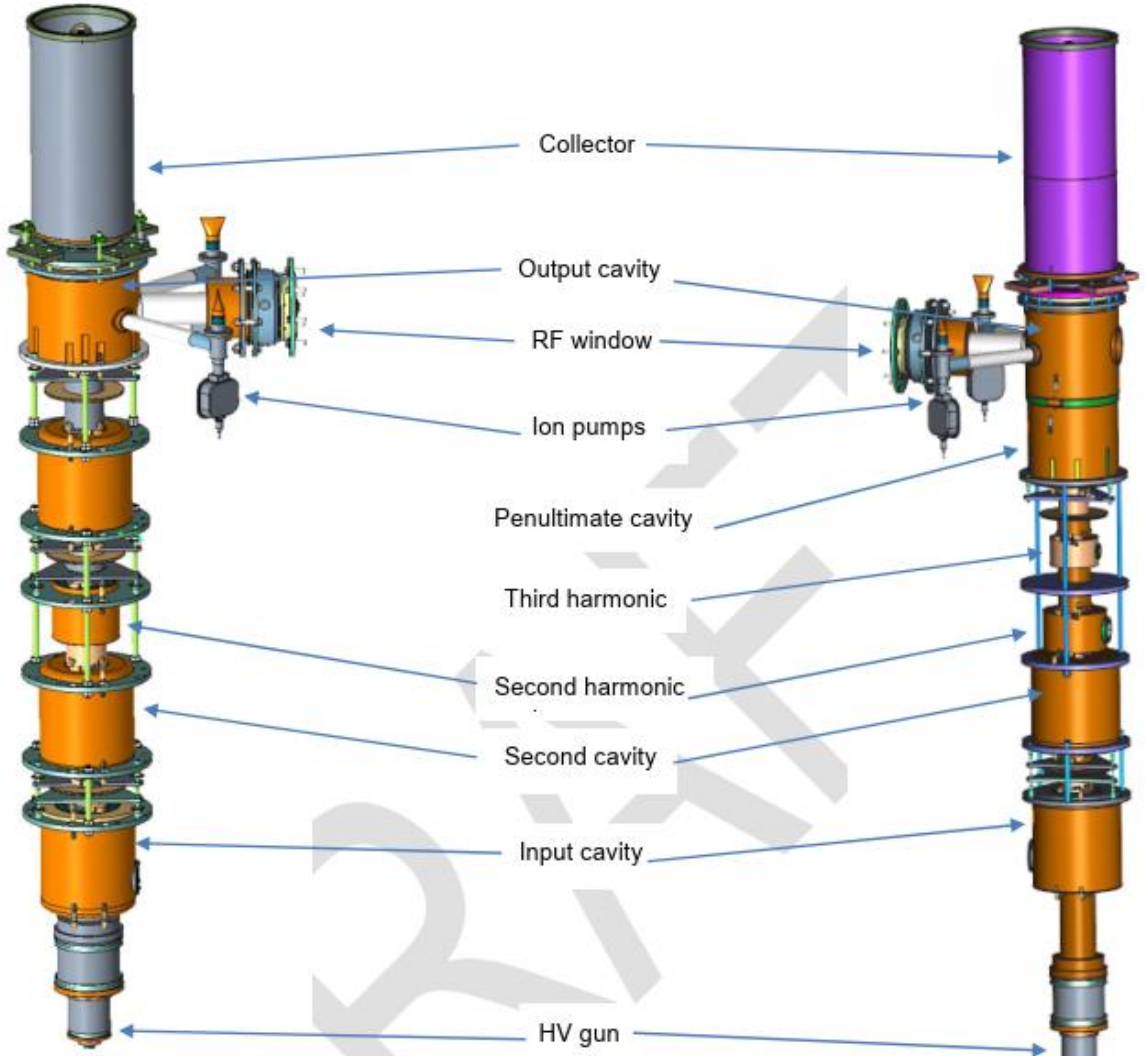


Figure 48 : Pumped TH2167 klystron view

Figure 49 : Pumped TH2167 HE klystron view

New TH2167 HE klystron

Core Oscillation Mode (CS) method with six cavities including a second and third harmonic

Same electron gun and window

Slightly modified solenoid

New collector

Same frame and dressing as possible

Hardware modifications

New collector:

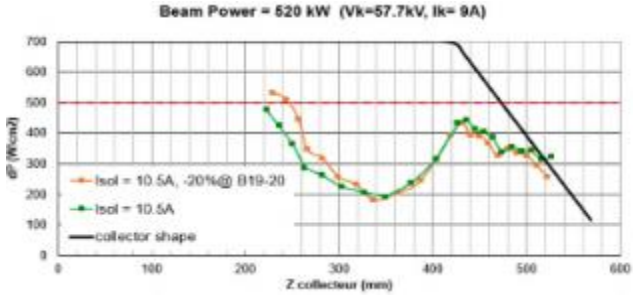
- New design to stand a larger power and reduce local heat deposition
- Slightly longer length. Still compatible with frame and installation in LHC
- Modification of the piping

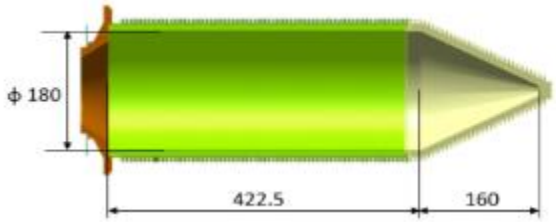
Solenoid:

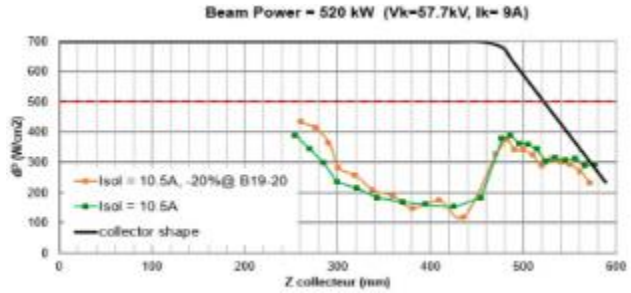
- Re-distribution of coils longitudinally to adapt to the new geometry

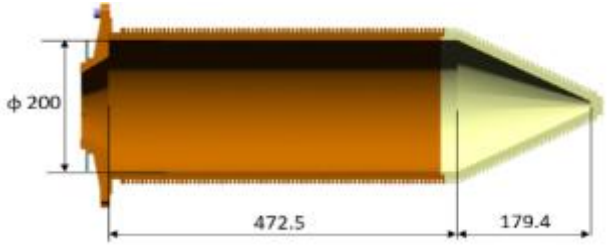
Changes to the assembly technology

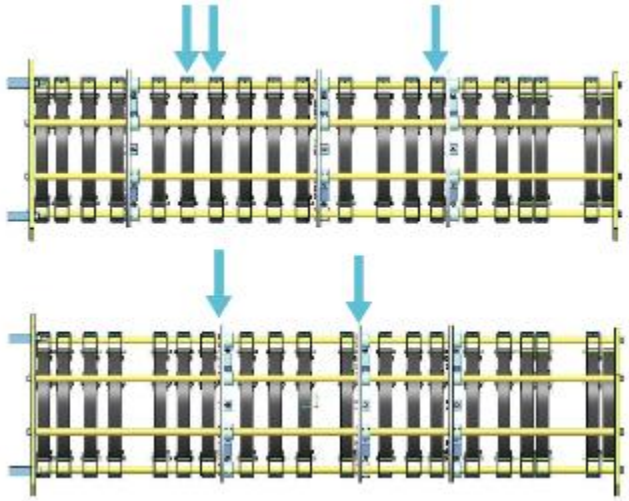
New tooling

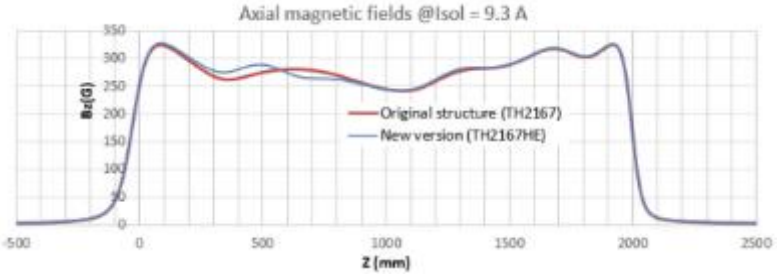












Updating the support frame

- Current frame needed modification to adapt to new radiation norms at CERN
  - 1uSv/h at 10cm from any accessible surface
- Lead and gridded panels added to the frame
- Connectors, cable routing, feedthroughs needed updating

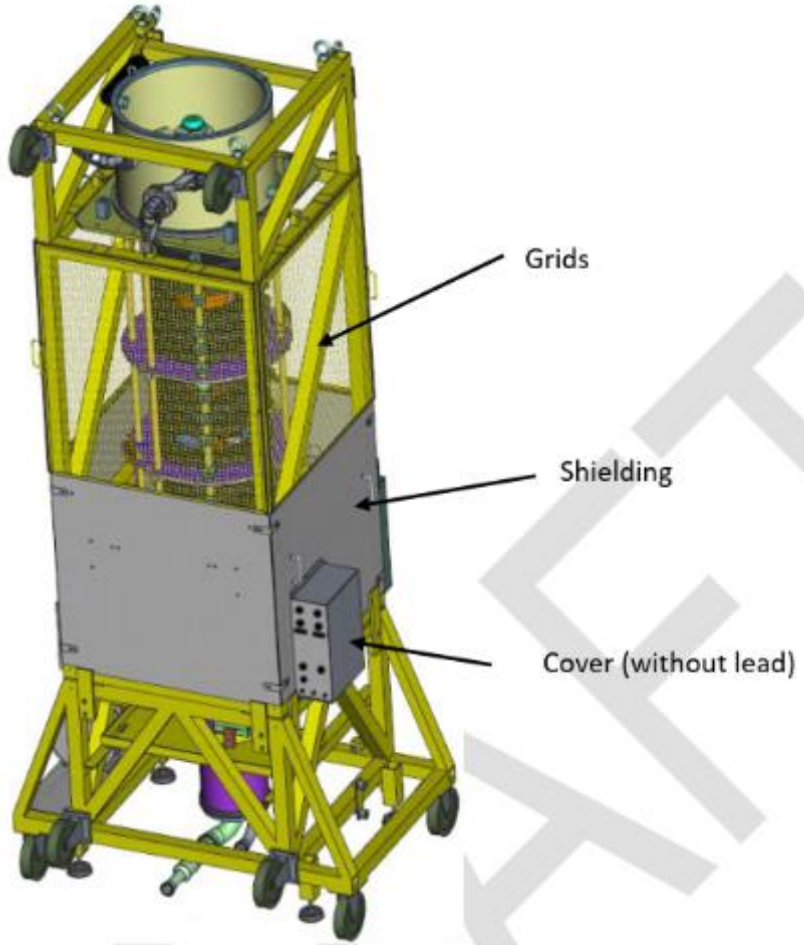


Figure 72 : Removable shielding and grids

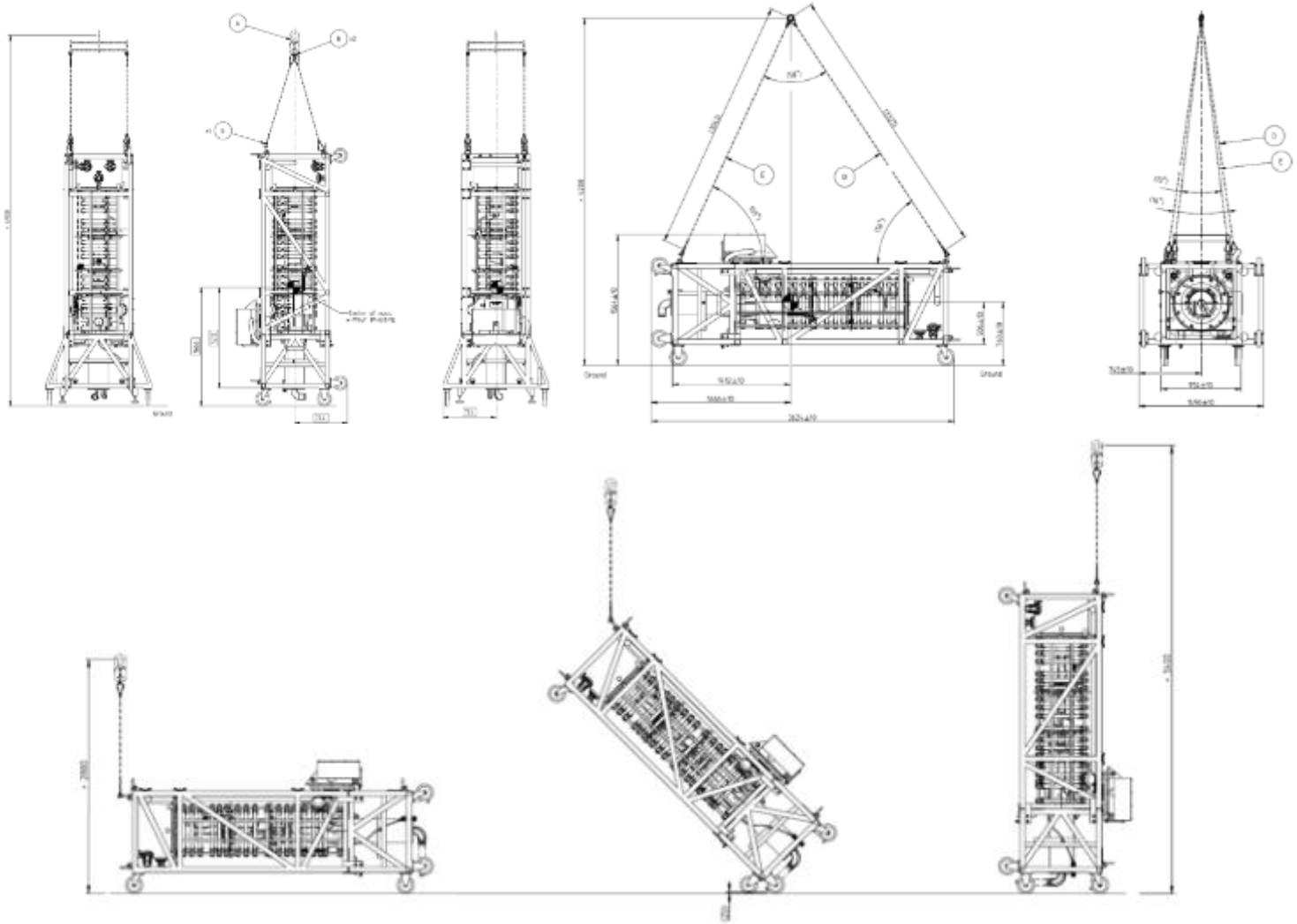
New safety calculations

Structural calculations with new added elements

For transport and handling including turning the klystron

Current frame and attach points can be reused

Panels to be removed during transport except for vertical handling



Fabrication

St Paul sent back to Thales after a vacuum failure (SN.001)

Striped and dismounted

Vehicle test: Last two cavities fabricated and assembled

Successfully tested in vacuum and RF for tunability

Procurement of the dressed tube parts ongoing

Collector and gun ready

Schedule

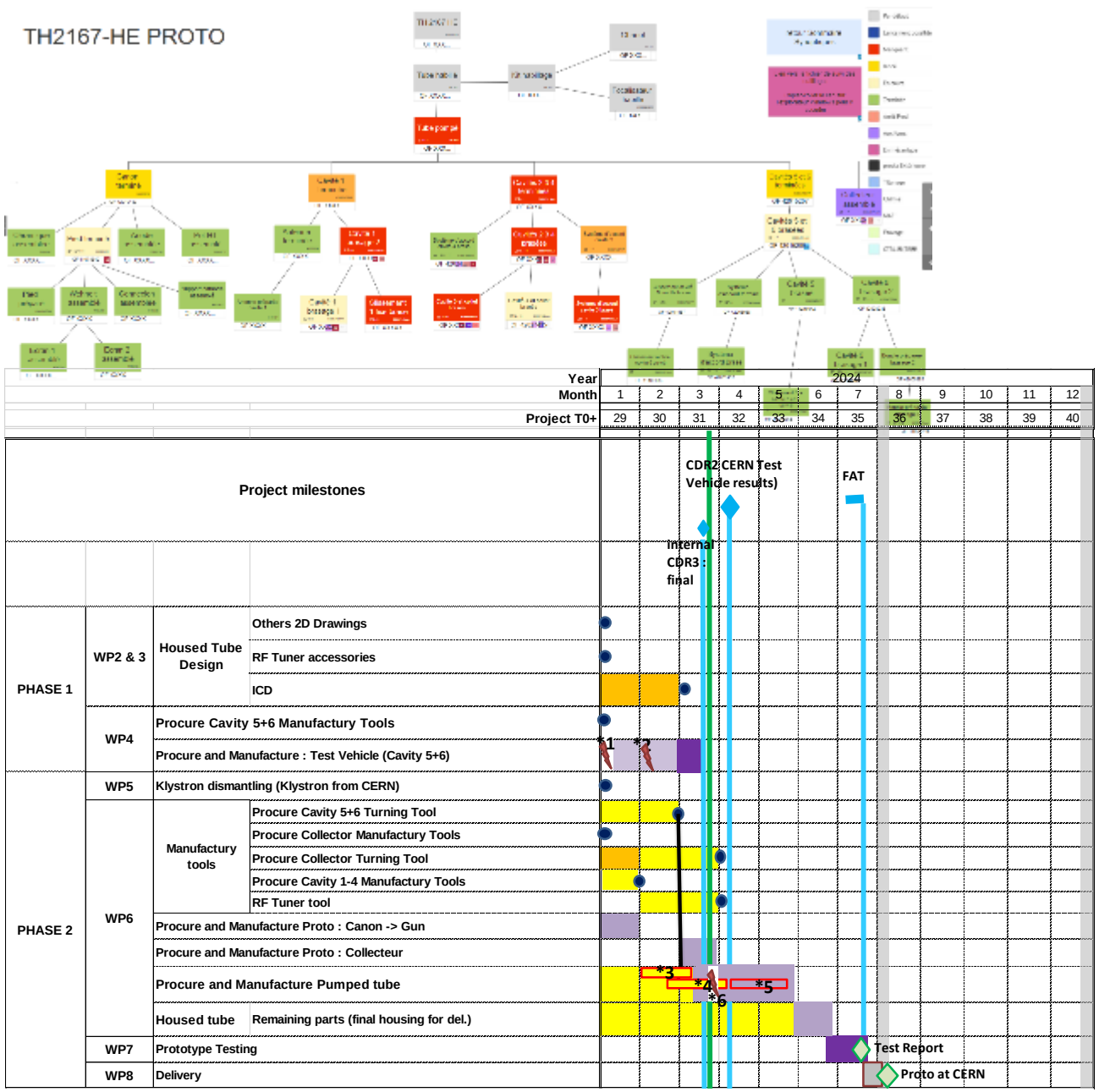
Assembly well advanced. Some procurement still on-going

Priority at Thales for assembly and procurement

CDR review initially split in two. Both done now

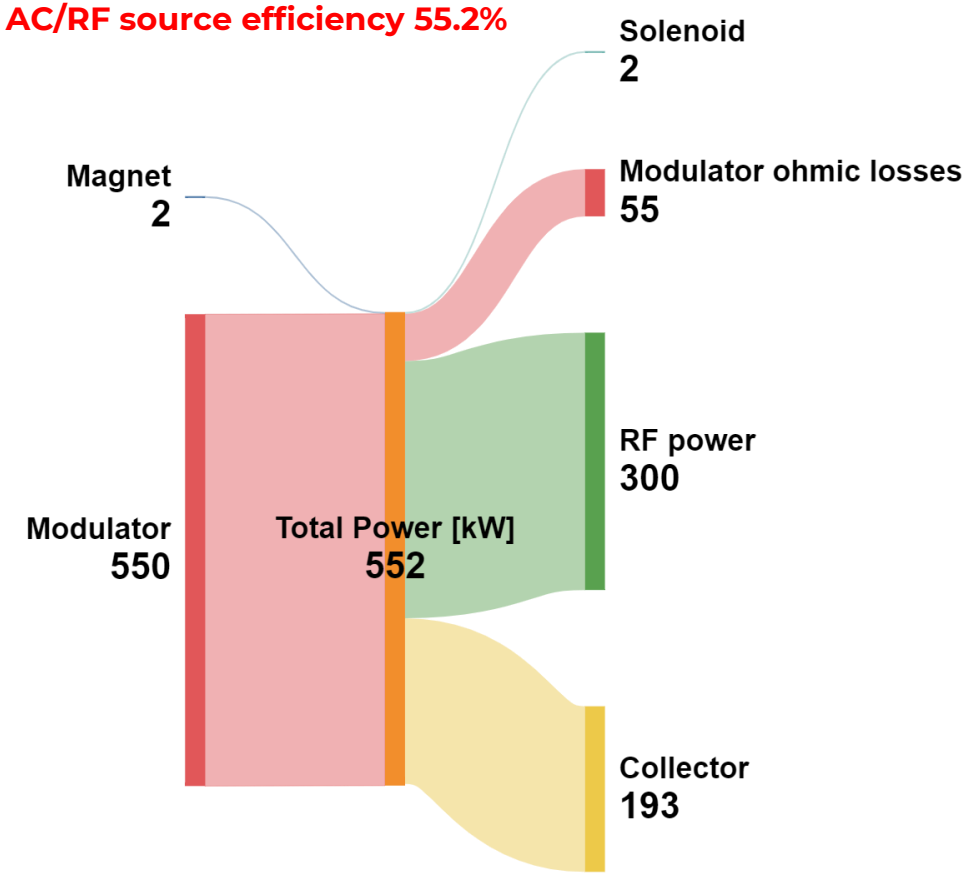
Klystron expected at CERN in July

Maintenance in Thales test facility may require the prototype to be tested directly at CERN

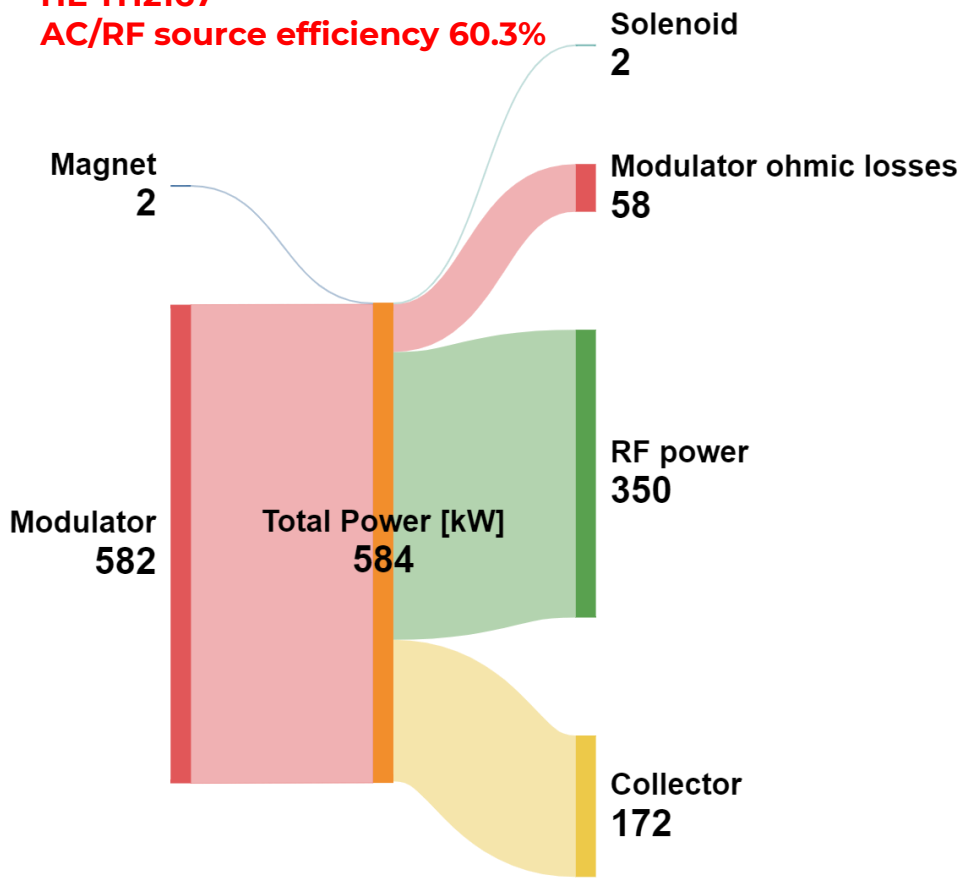


Power balance (SAC recommendation)

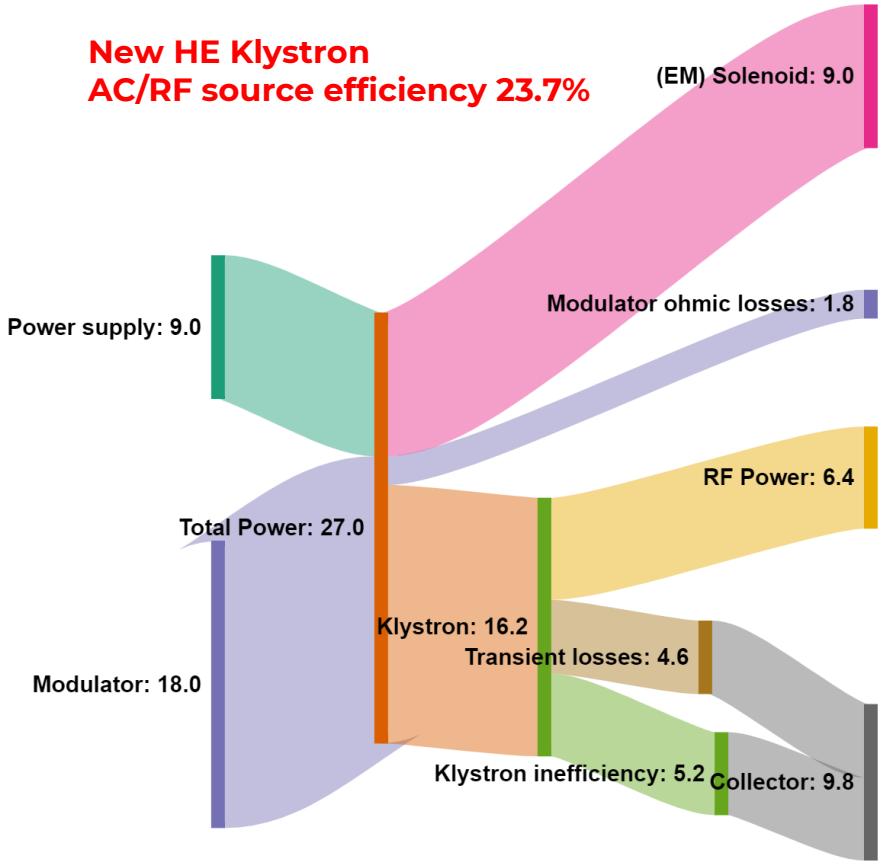
TH2167
AC/RF source efficiency 55.2%

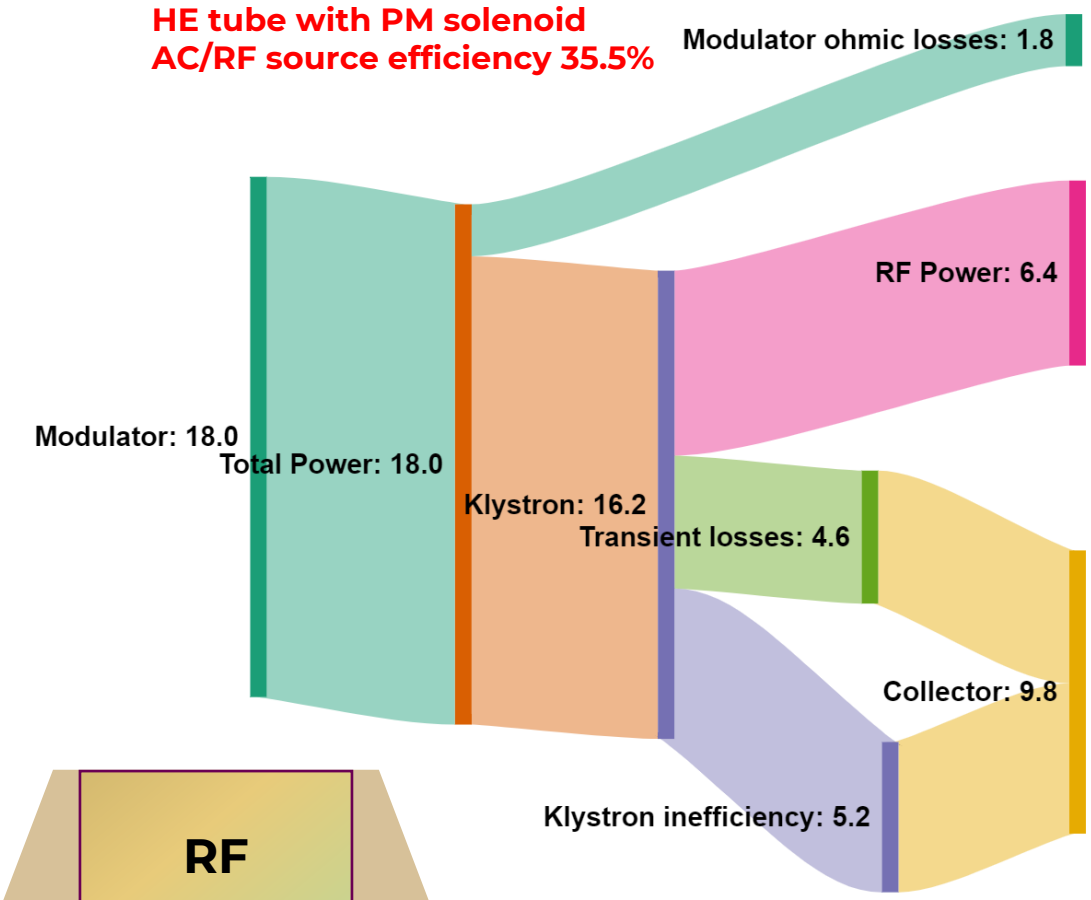


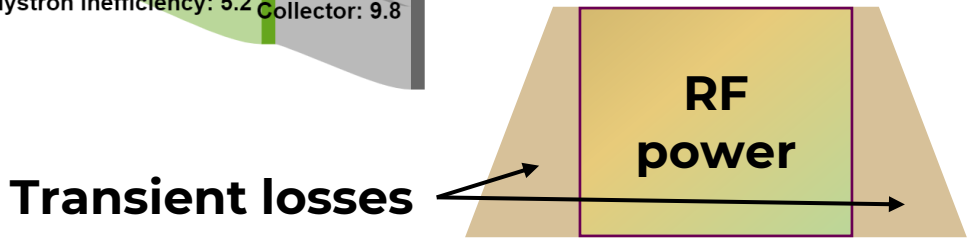
HE TH2167
AC/RF source efficiency 60.3%



Power balance for pulsed RF sources







Conclusion and Next steps

- Effort required to produce the prototype somehow underestimated
  - New norms, techniques, obsolescence, procurement difficulties…
- Prototype expected in summer and tested in Autum
  - Still compatible with IFAST time frame
- Monthly follow-up meetings between CERN and THALES
- Maintenance of the Thales test facility to be monitored closely
- At CERN: Preparation of test facility in building 112
- Mutual interest in future collaborations beyond the current project

iFAST

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under GA No 101004730.