RadiaBeam

An RF beam Sweeper for Purifying In-Flight Produced Rare Isotope Beams

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RadiaBeam

- Founded in 2004
- ~50 employees and growing
- 30,000 ft^2 headquarters in Santa Monica, CA

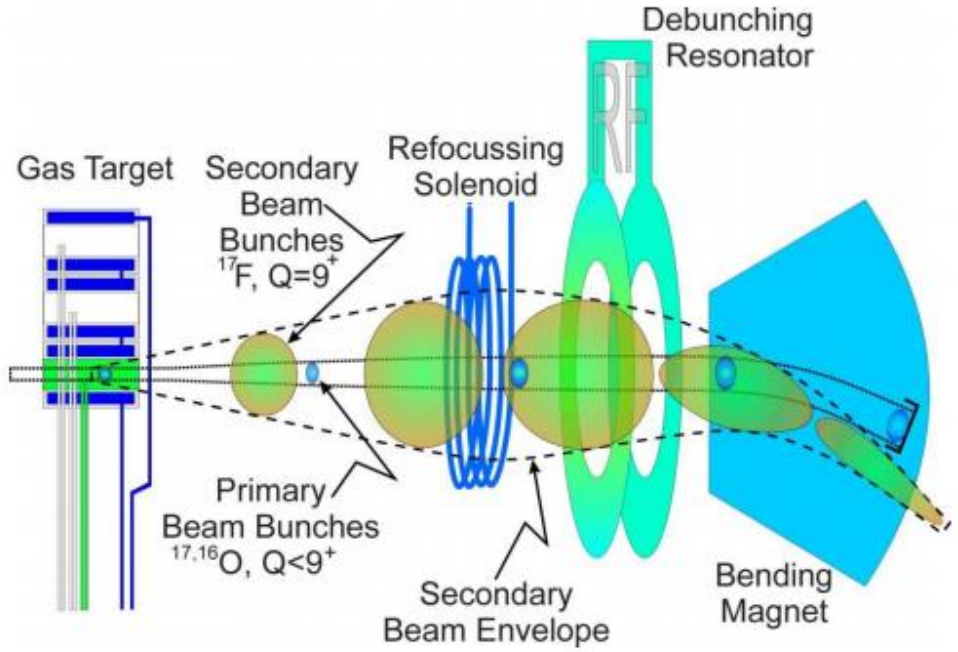
- Accelerator R&D, design, engineering, manufacturing and testing all under one roof in a dynamic, small-business setting

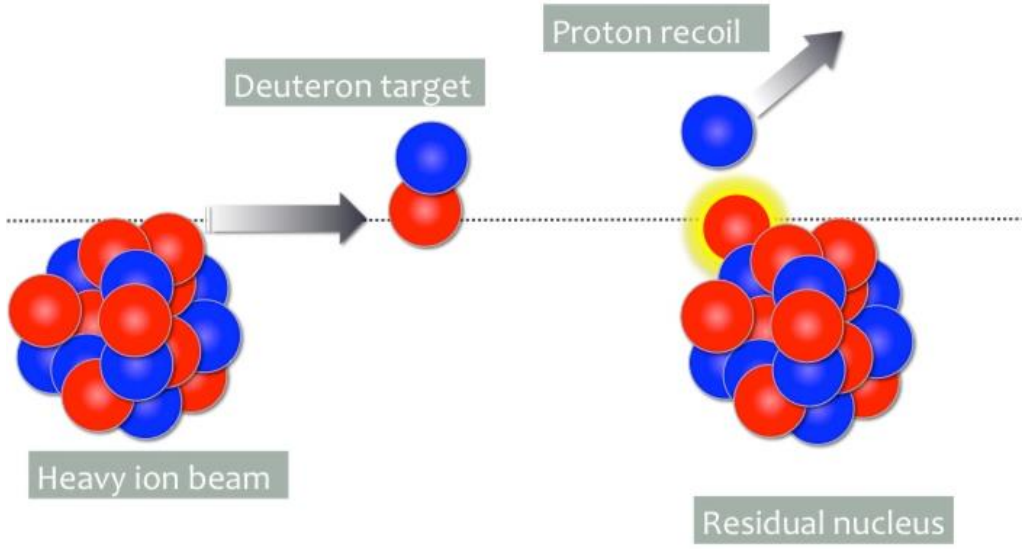
Tour: Machine Shop

- Multiple CNC milling and turning centers, > $3 million investment
- Dedicated “clean shop” for RF and UHV machining
- Full-suite of inspection equipment, including CMM
- 10 highly-skilled machinists
- ISO 9001 compliant quality system

Motivation

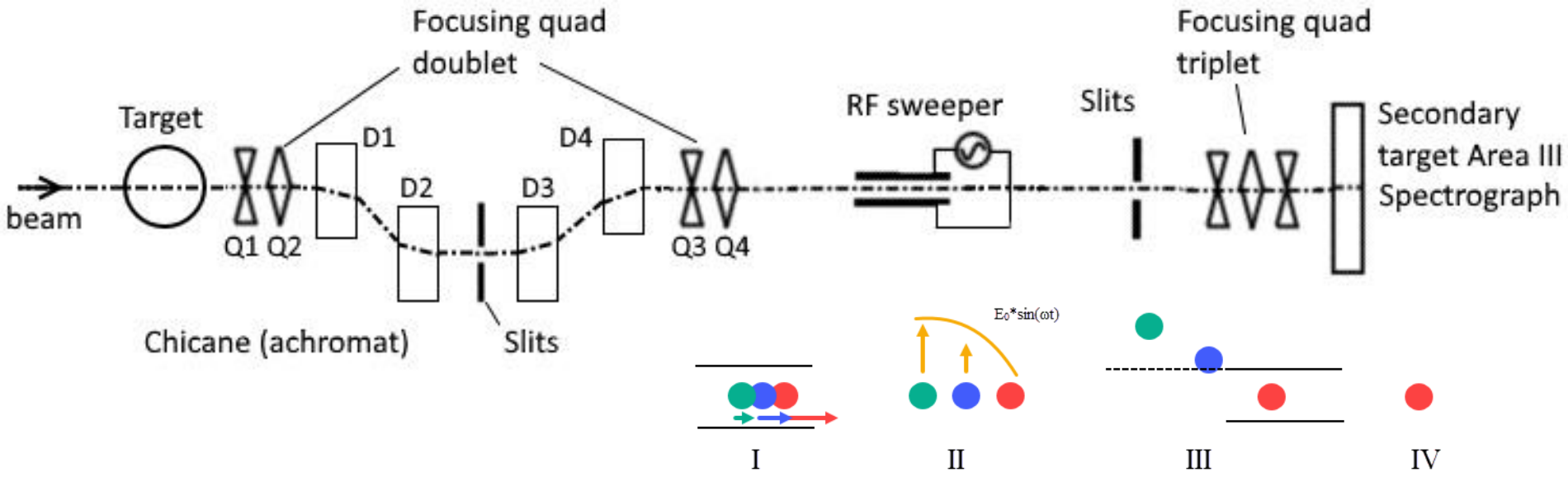
- Secondary radioactive beams are produced when a primary beam hits the target
- Other low-energy isotopes are produced during this process
- The isotopes different from the required isotopes must be filtered





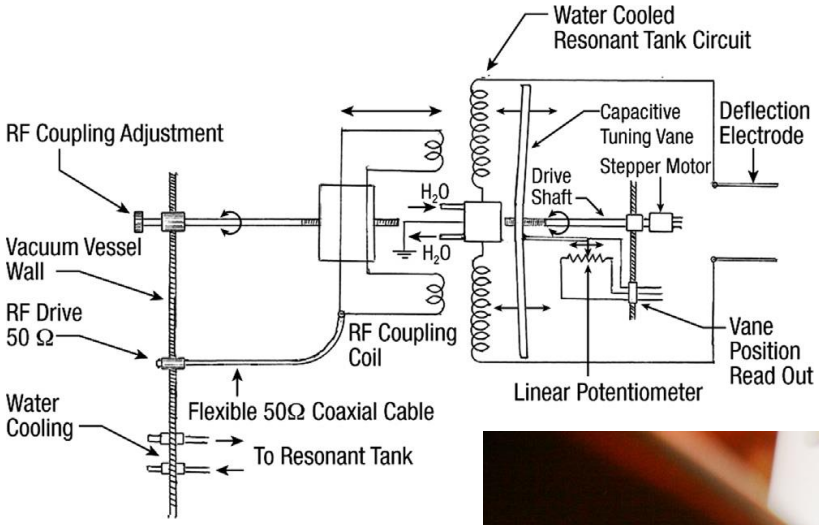
Fragment separation

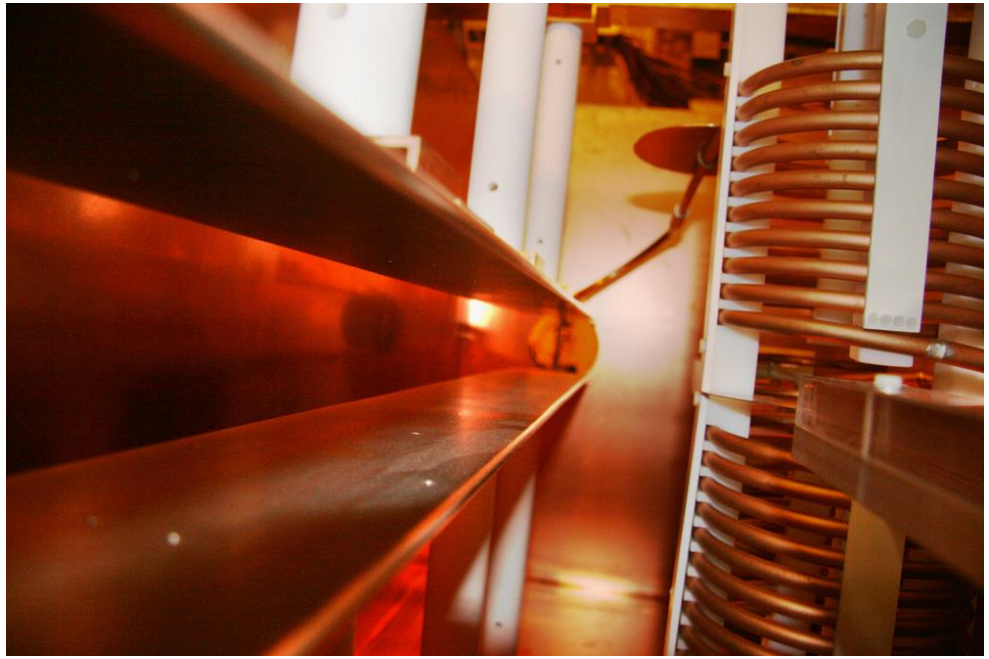
- In ATLAS, a chicane magnetic fragment separator is used to filter the unwanted isotopes, as some isotopes can still pass through this separator
- Velocity selection criterion is needed



Existing sweeper

An existing RF sweeper provides with 55kV kick at 6 MHz (~1 kW input power)

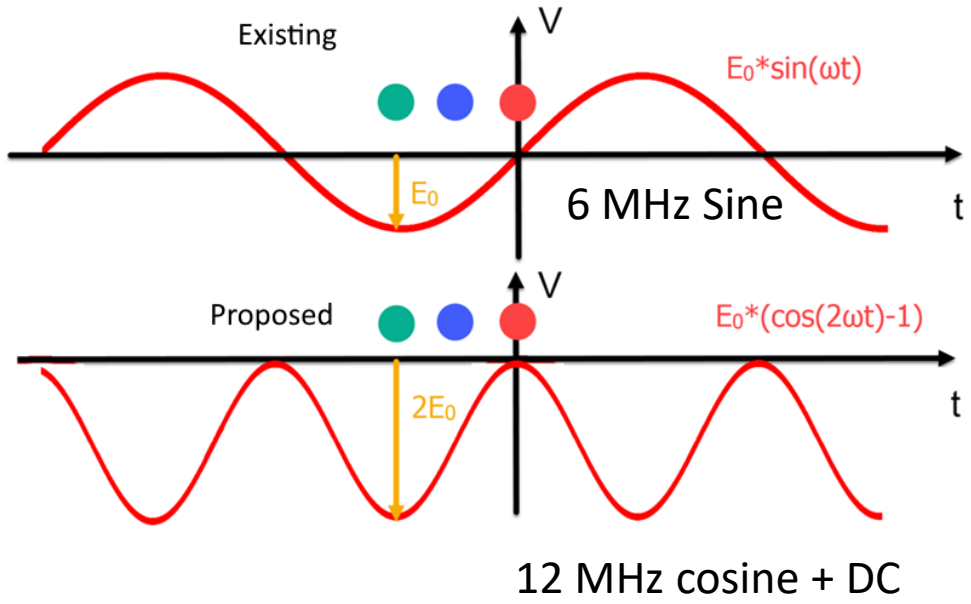




New sweeper parameters – Version A

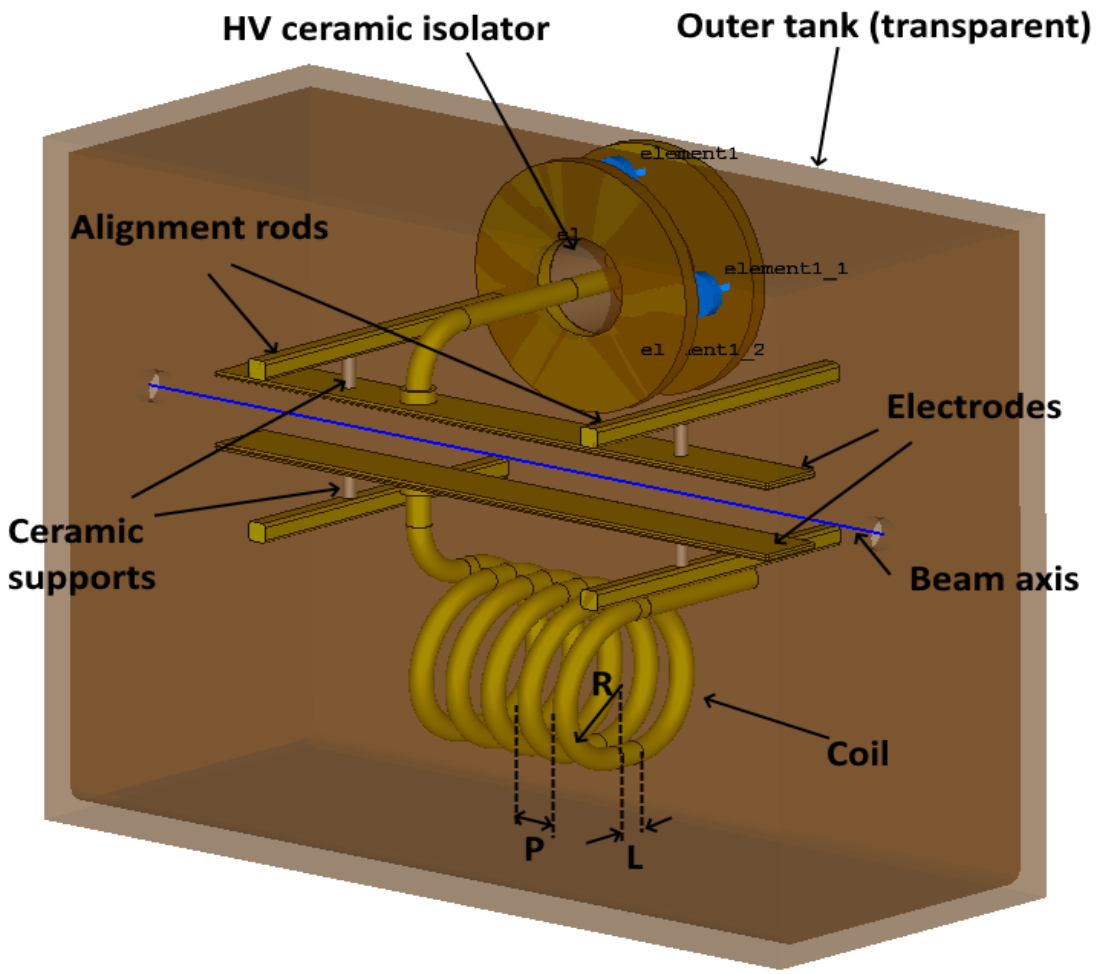
- The deflecting voltage should be 3x higher than the existing ATLAS separator (which is 55 kV at 6 MHz)
- The dimensions are limited to 1 m
- It was proposed to increase the frequency by factor of 2 and overlap RF deflection with DC bias to achieve the same deflection as pure 150 kV RF kick at 6 MHz
  - Cosine instead of sine

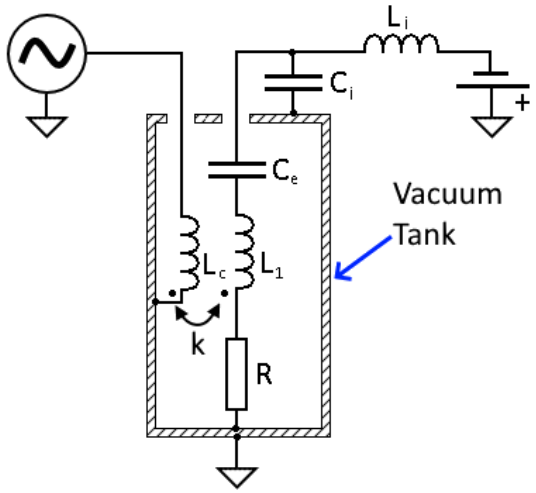
Fragment purity improvement	>5 times
Operating frequency	12 MHz
Deflecting voltage	150 kV (75kV from RF and 75 kV from DC)
Secondary beam energy	3-10 MeV/u
Charge-to-mass ratio	varies
Aperture	10 cm



Version A parameters and design

- We designed a 12 MHz sweeper based on 'lumped' elements that allows 75 kV RF kick + 75 kV DC kick



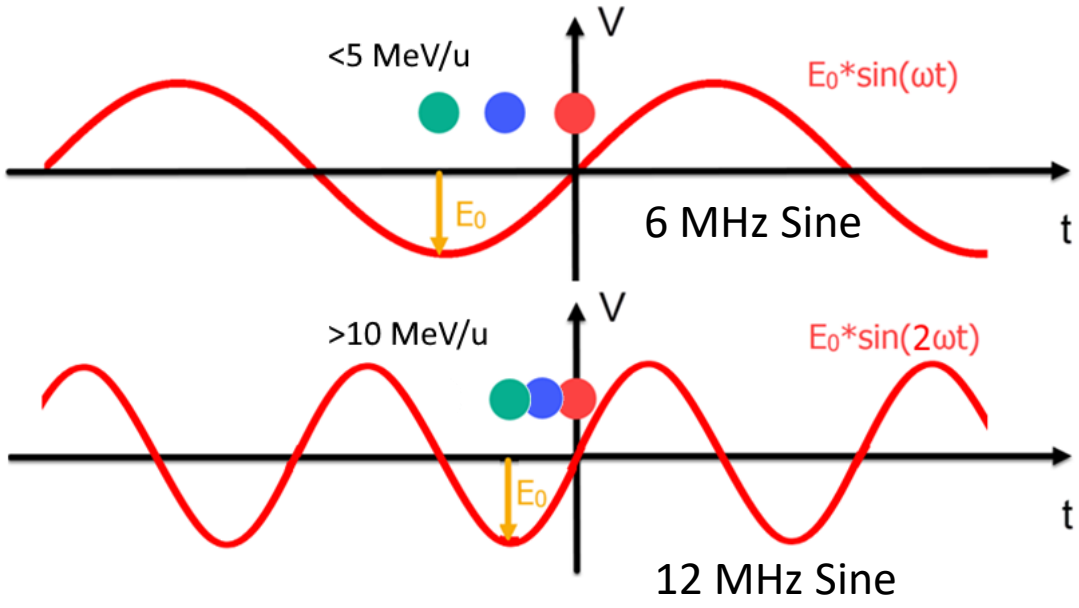


Fundamental frequency	12.125 MHz
Deflecting voltage	150 kV
RF power	2.6 kW
DC bias	75 kV
Length	1 m
Aperture (gap)	10 cm

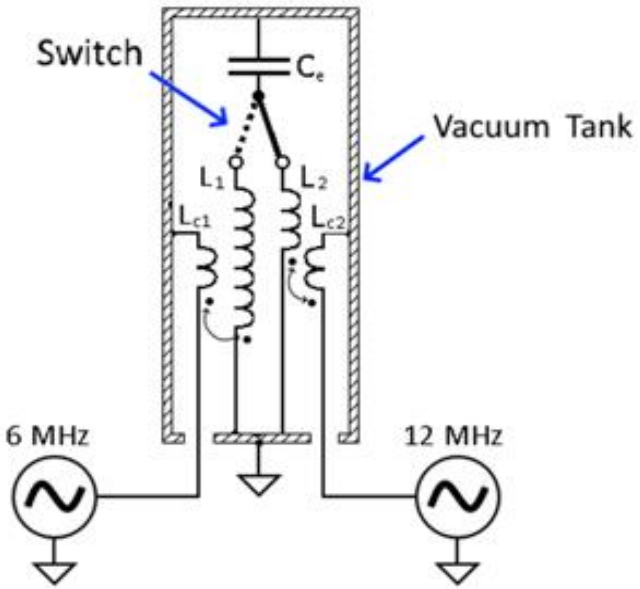
New sweeper parameters – Version B

- Cosine wave deflector's zero point is at the crest, it is very much non-linear around it and doesn't provide a good separation
- We proposed to redesign the kicker to provide purely RF kick of 150 kV that can operate at 2 frequencies: 6 MHz and 12 MHz for different ion species.
- The frequency should be manually switched between the experiments in ~hours timeframe.

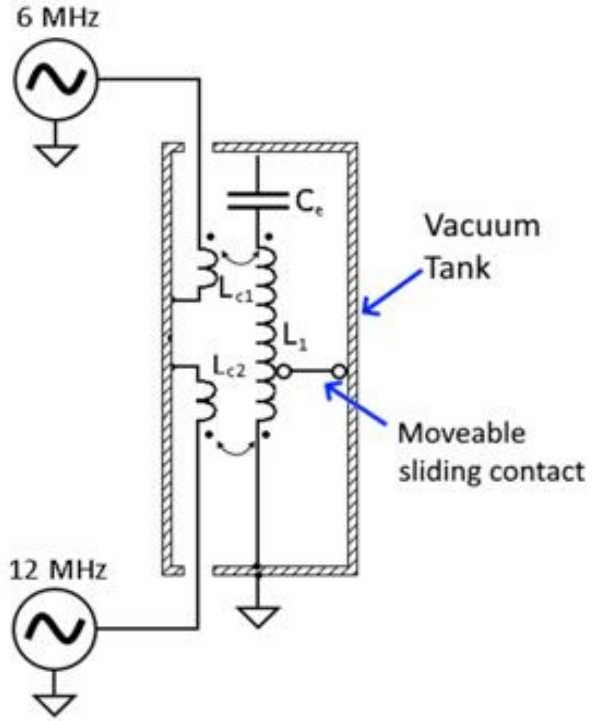
Fragment purity improvement	>5 times
Operating frequency	6 MHz and 12 MHz
Deflecting voltage	150 kV
Secondary beam energy	3-10 MeV/u
Charge-to-mass ratio	varies
Aperture	7.5 cm



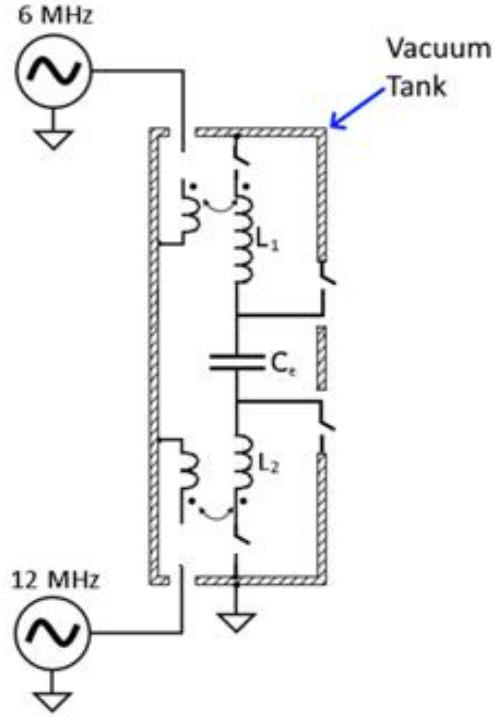
Principal schemes to allow dual-frequency operation



- In-vacuum switch:
  - Problem to connect RF and water inside vacuum volume



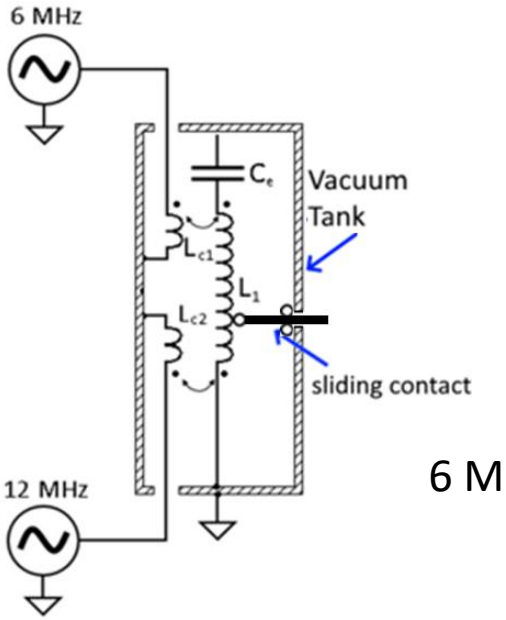
- Sliding contact:
  - Problem to connect RF and water inside vacuum volume
  - Very large coil

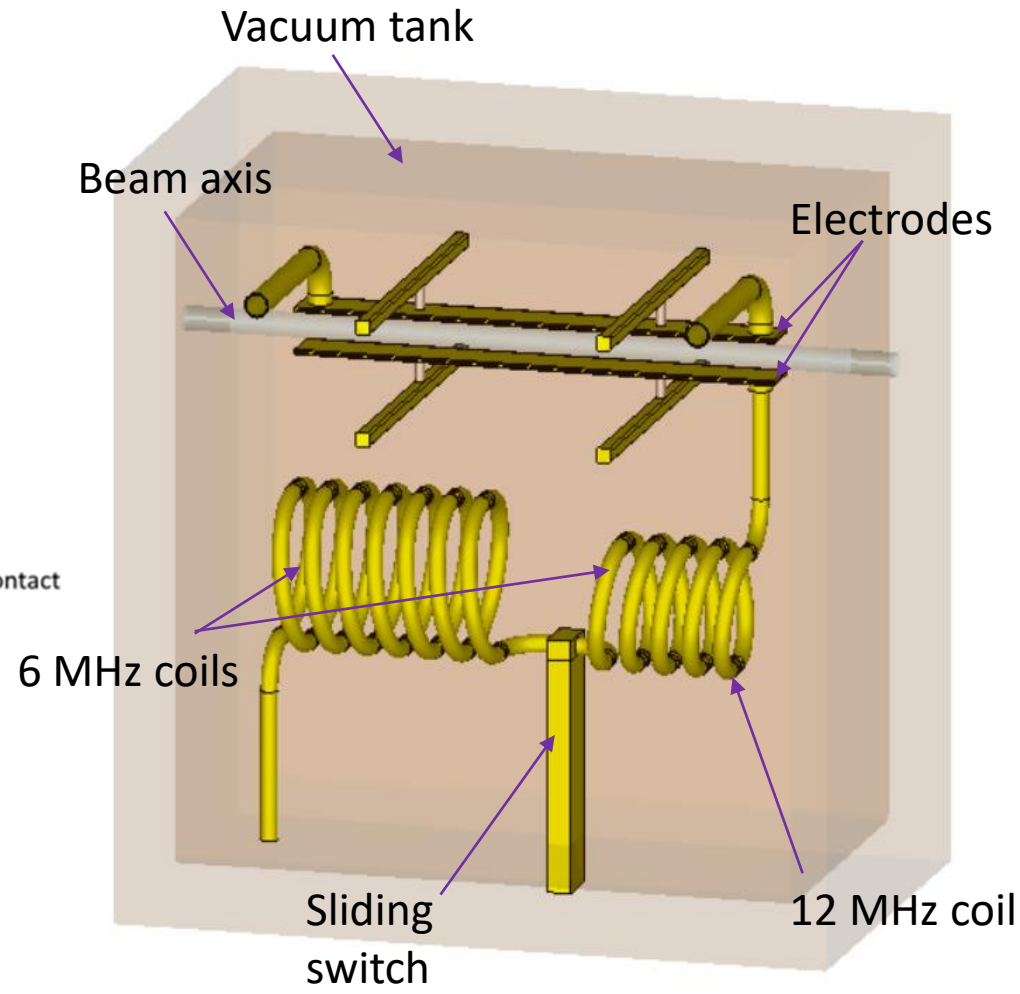


- Ground switches:
  - Allows water flow thru both electrodes
  - RF leakage

Version B parameters and design

- We designed a new sweeper based on 'lumped' elements that allows two operation regimes each providing with 150 kV kick





Frequencies	6 + 12 MHz
Deflecting voltage	150 kV
RF power	~9 kW
Length	1 m
Aperture (gap)	7.5 cm

Version B parameters and design

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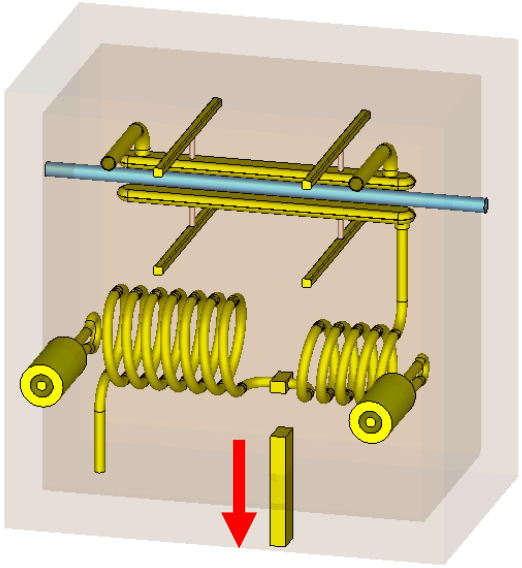
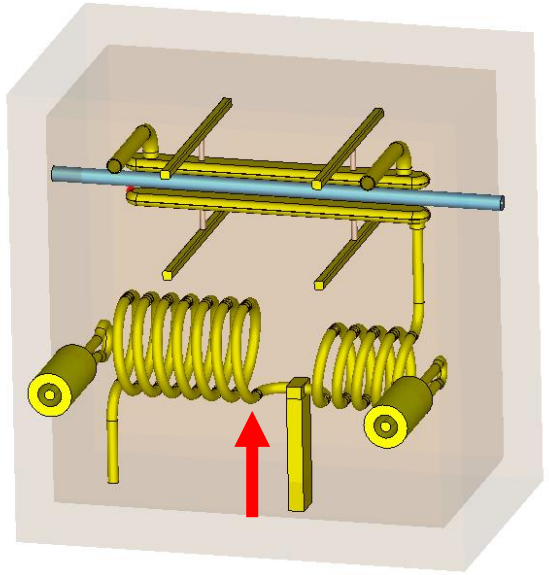
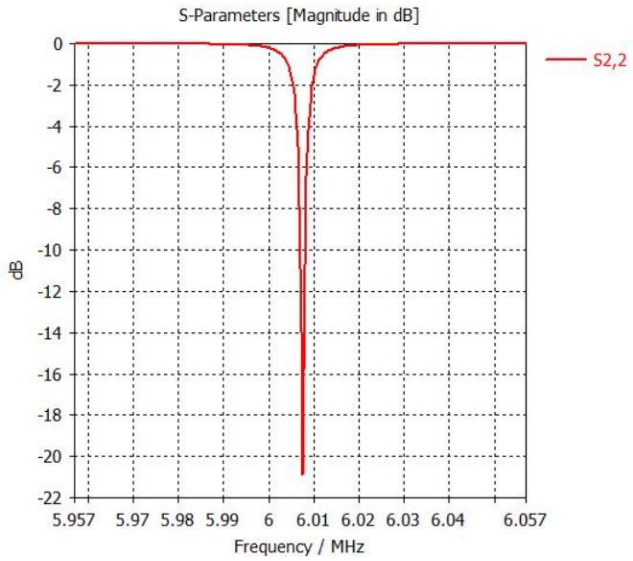
6 MHz mode

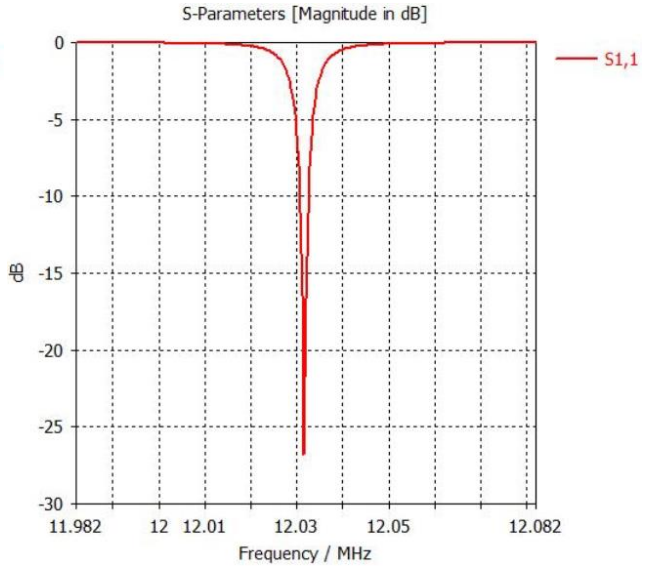


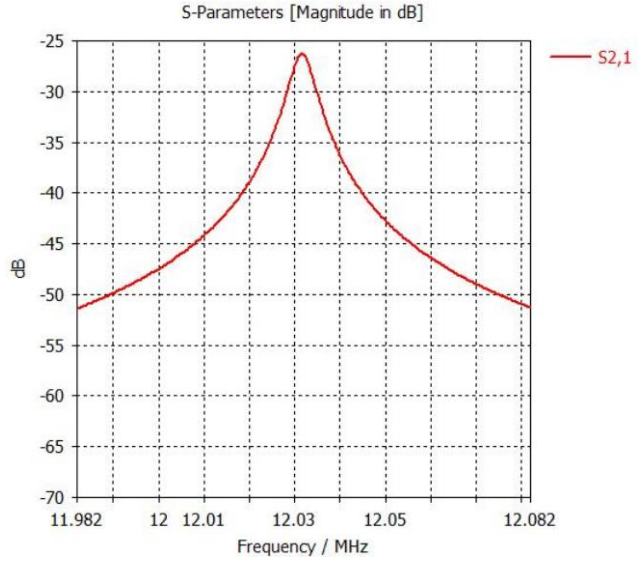
12 MHz mode



Parameter	6 MHz	12 MHz
RF power for 150 kV	8100 W	9850 W
Coil dimensions	Coil 1: 7 periods, D=290 mm, H=455 mm, Coil 2: 4.5 periods, D=232 mm, H= 292.5 mm	Coil 2: 4.5 periods, D=232 mm, H= 292.5 mm
Coil pipe ID/OD	29 mm/35 mm	
Vacuum tank	L×W×H 1280 mm × 750 mm× 1000 mm	
Ground legs pipe ID/OD	44 mm/50 mm	
Kp	4.7 MV/m	5.7 MV/m
Peak E (150kV)	5.37 MV/m	5.43 MV/m
Peak E (150kV)/Kp	1.14	0.95







Thermal study

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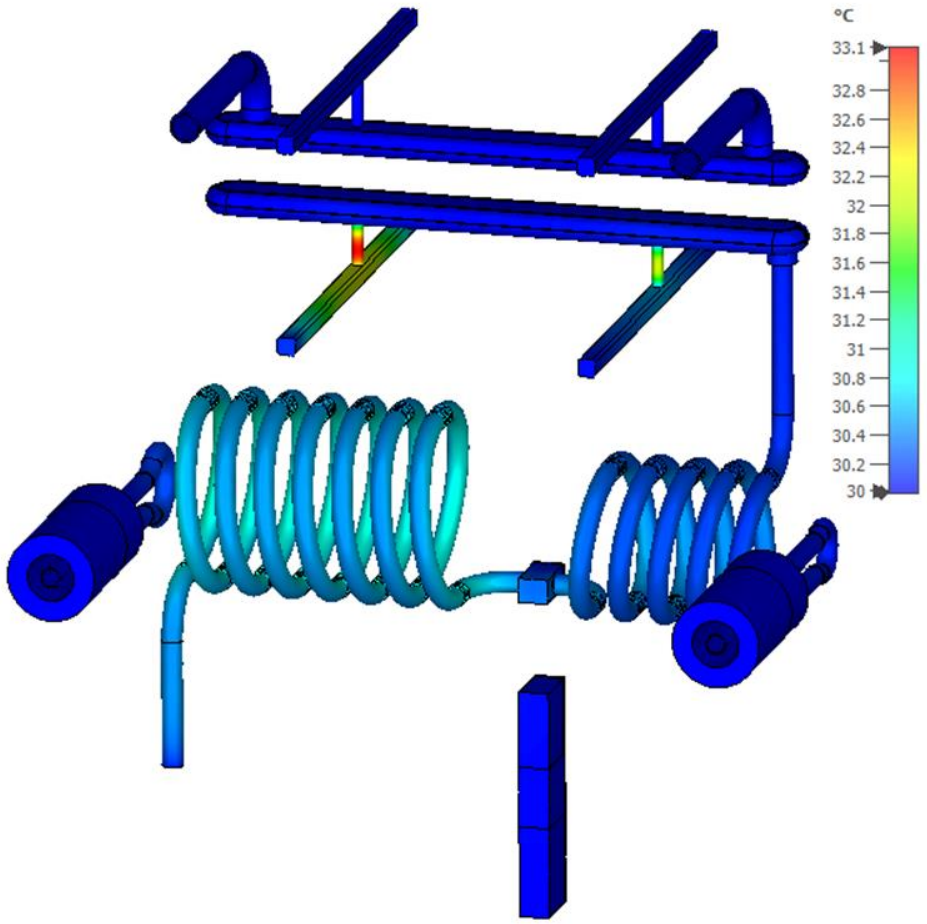
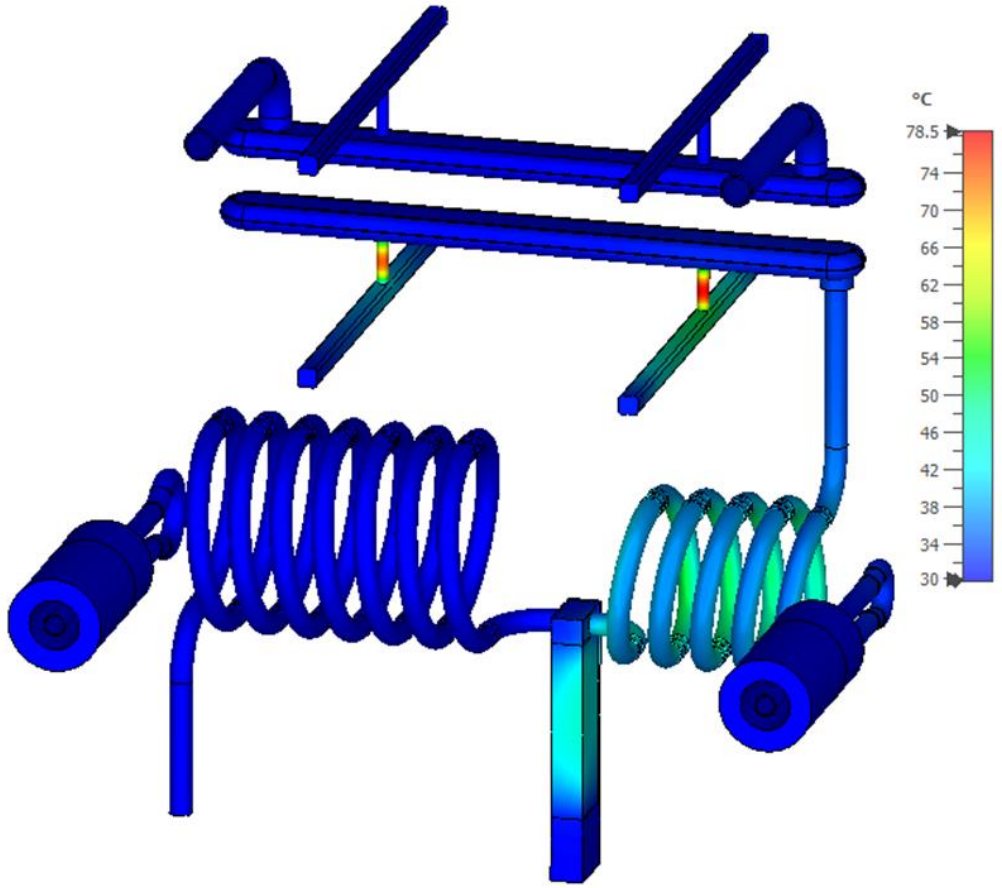
6 MHz mode

Water flow 10 l/min

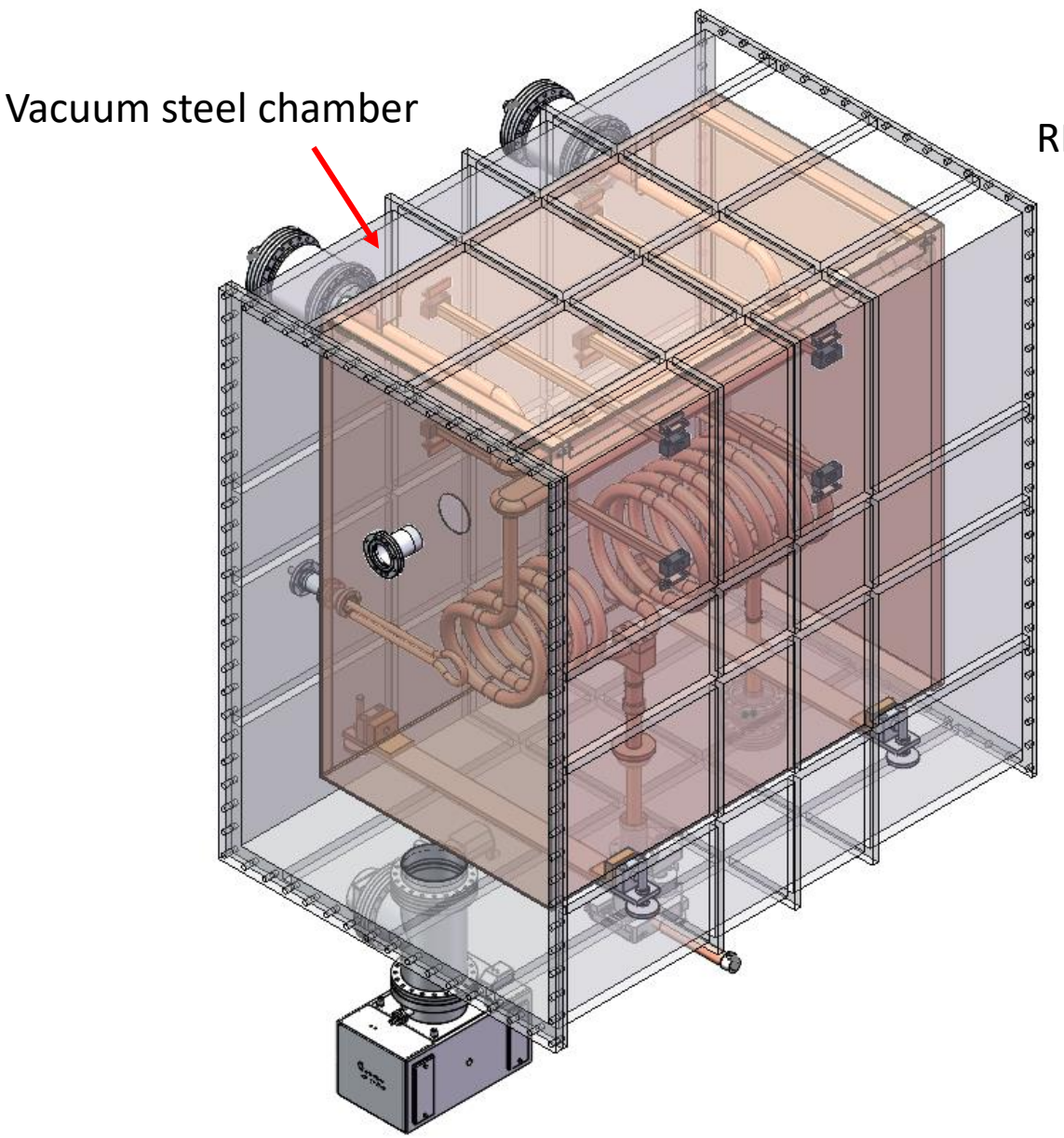


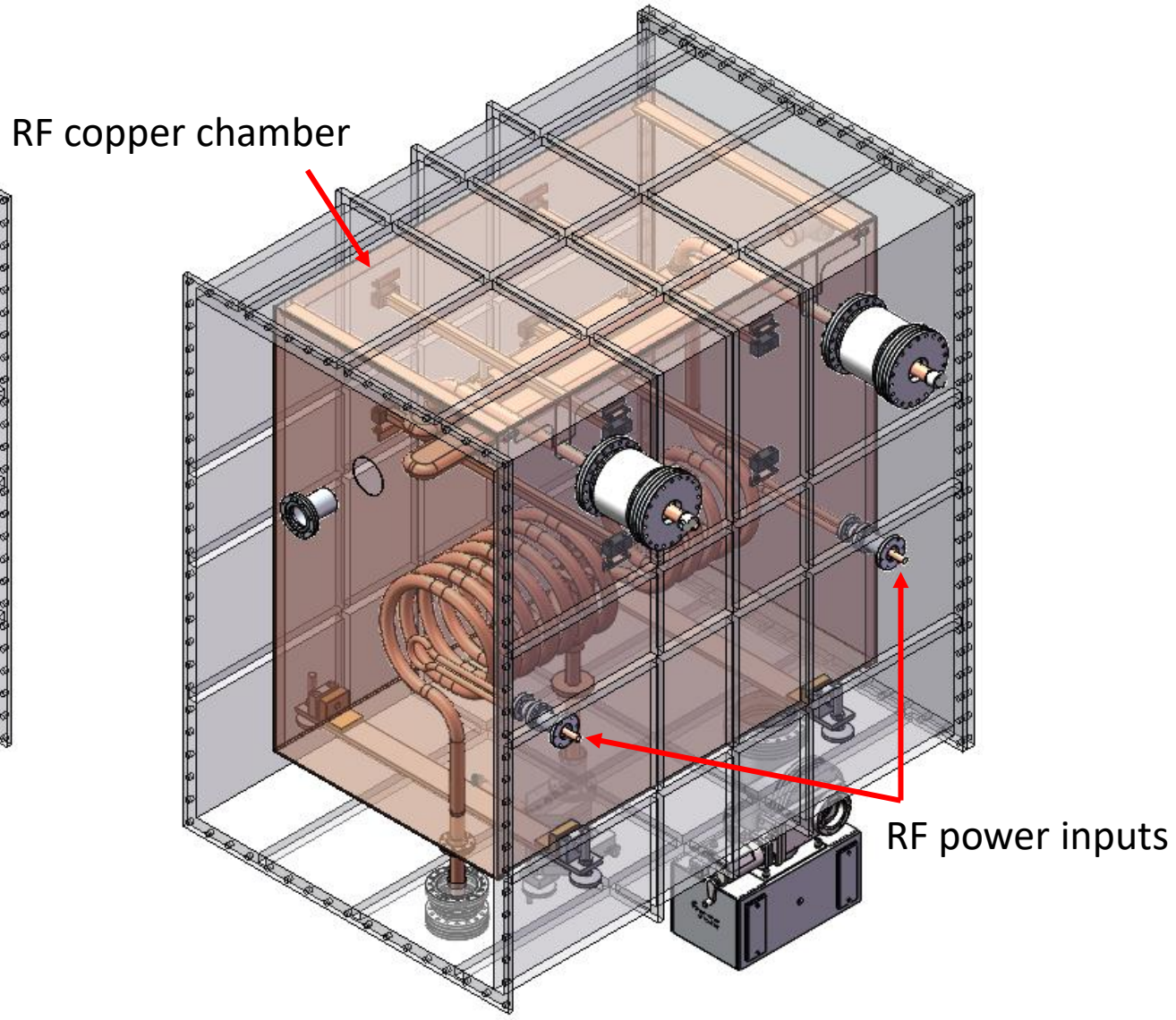
12 MHz mode

Water flow 20 l/min

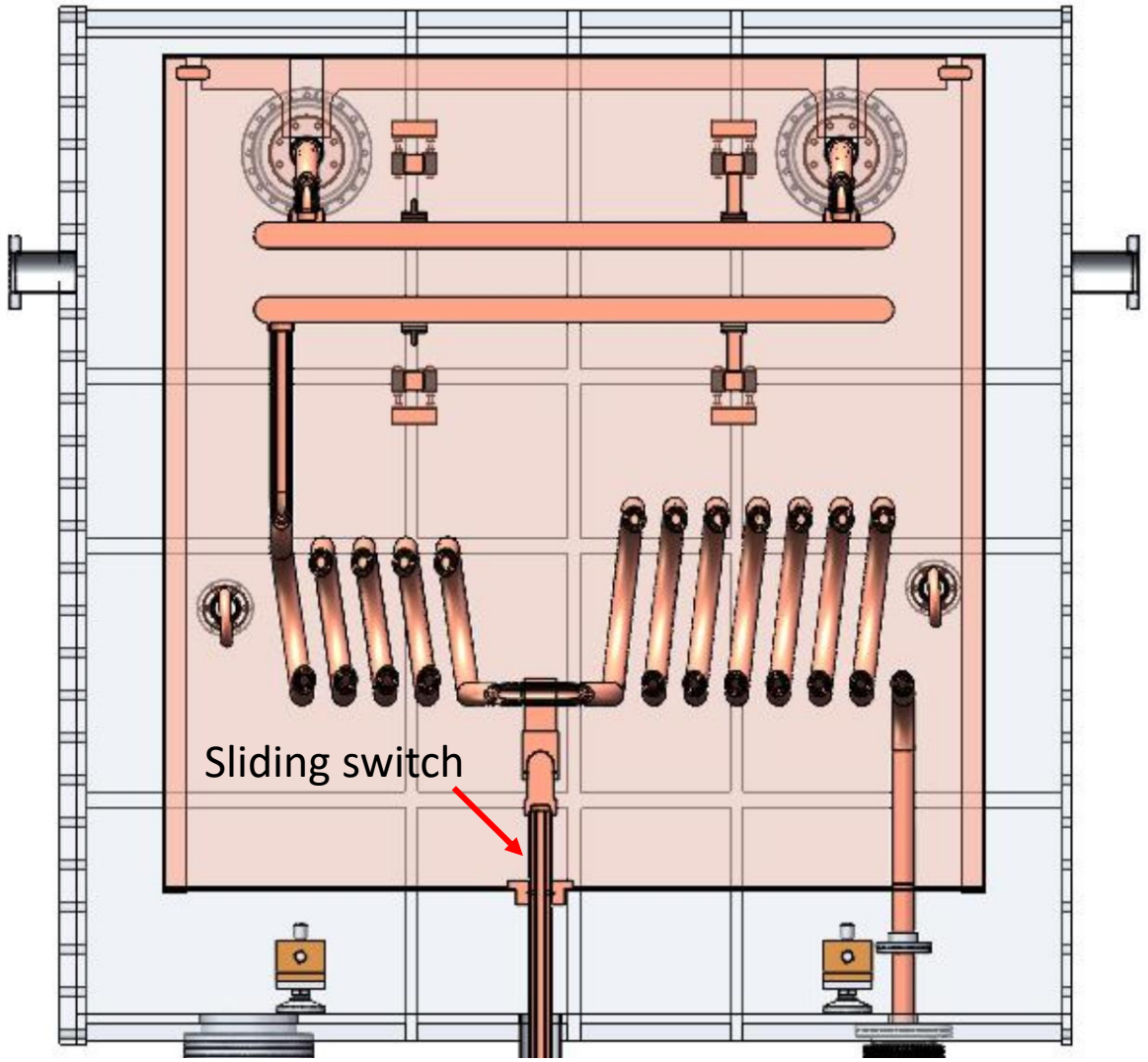


Engineering design

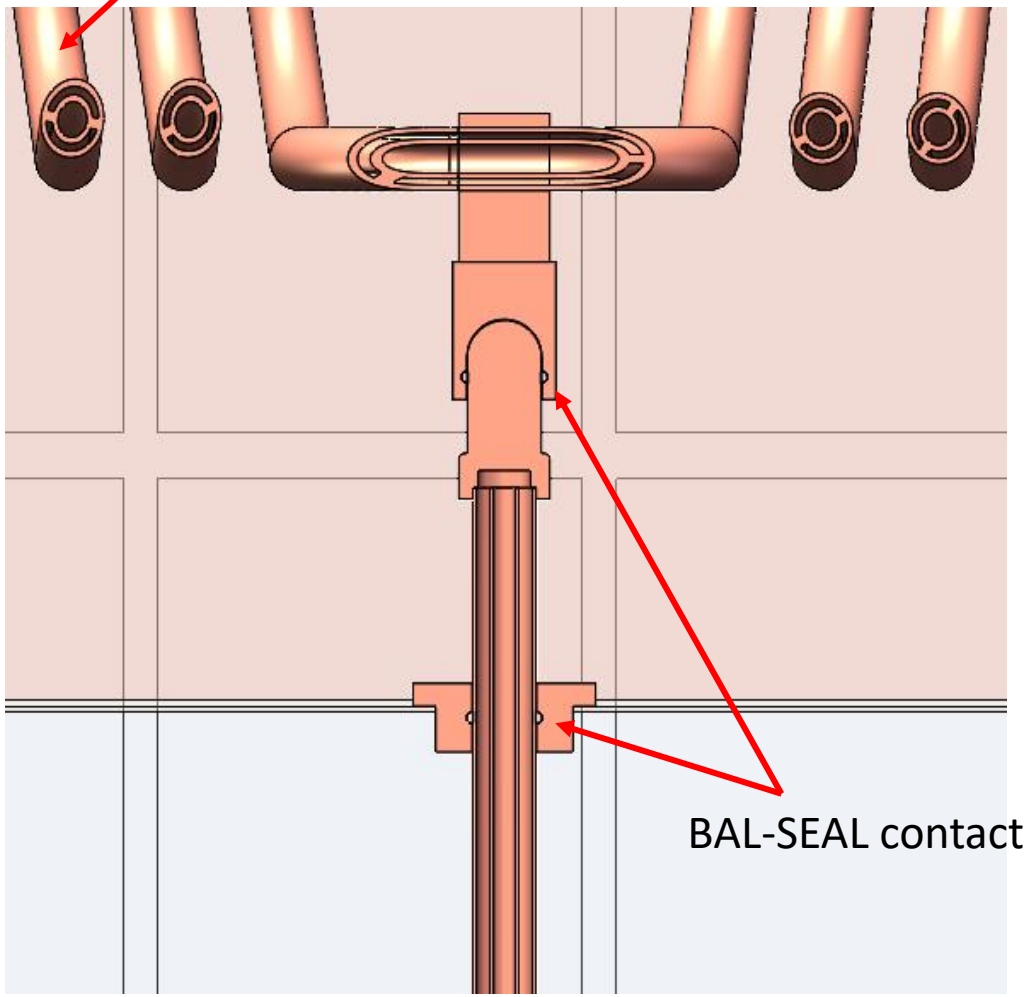




Engineering design

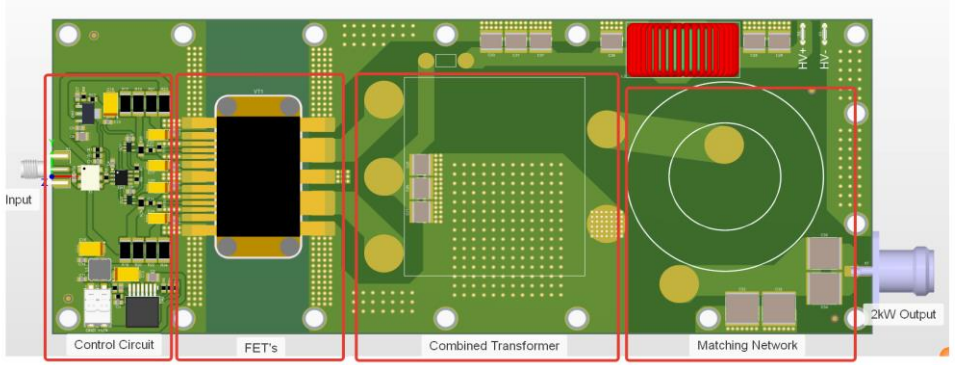


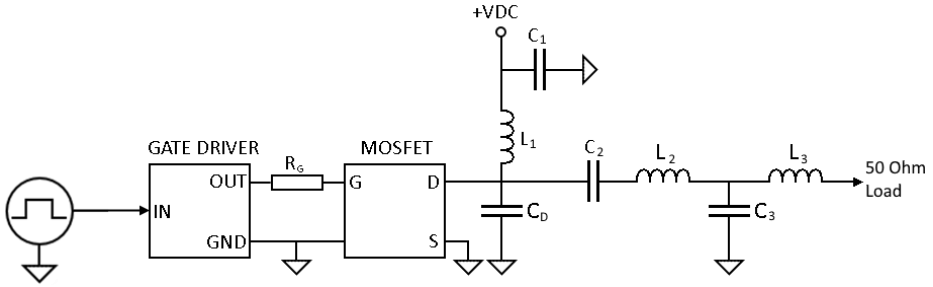
Tube-in-tube design

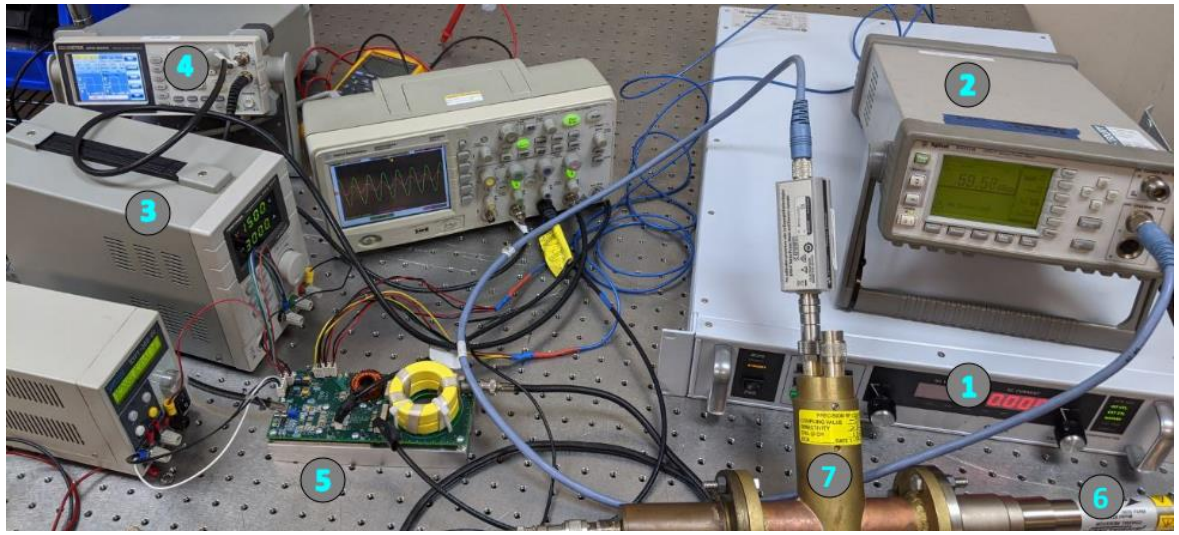


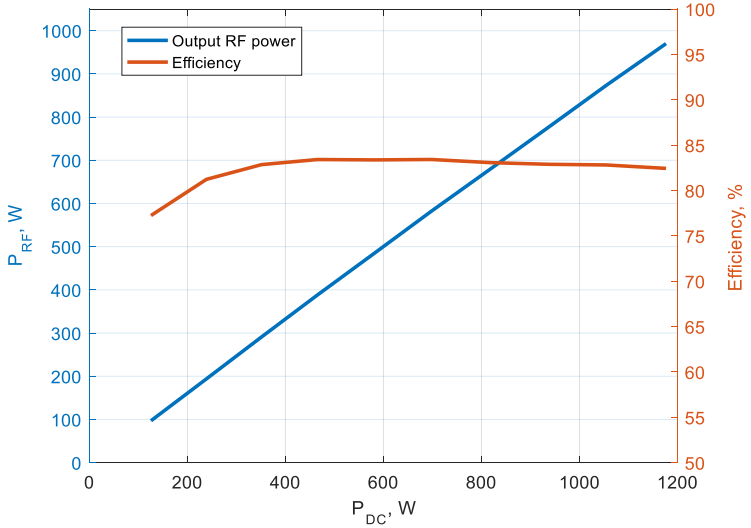
Solid-state RF source

- We designed and tested 12 MHz Class-E solid-state power amplifier
- Achieved ~1kW power at 82% efficiency
- The design for 2 kW pallet is ready and is currently in production









Summary and next plans:

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- Sweeper fabrication, assembling, leak and low-power RF validation.
  - April 2022
- RF amplifiers design, assembling and testing
  - December 2021
- High-power tests at Argonne
  - June 2022