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DEGLI STUDI  
DI PADOVA

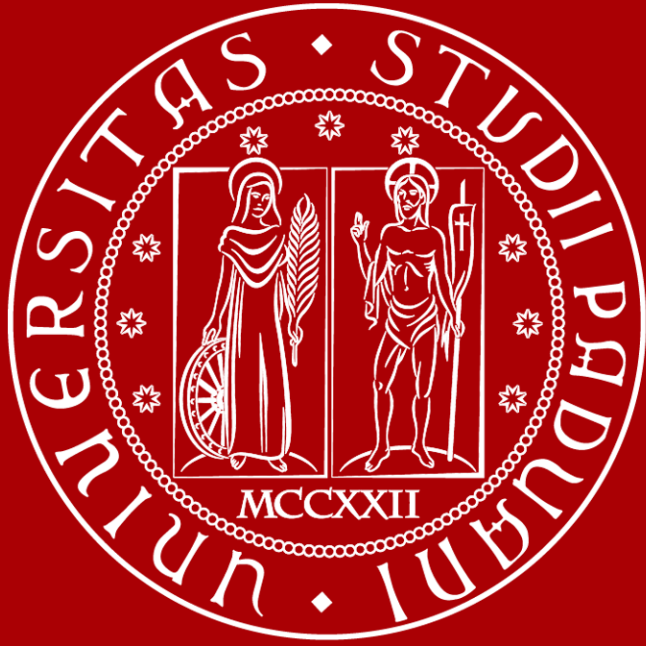
# Design and test of a radiofrequency cathode propelled with iodine

Renwei Tan - 40th Cycle

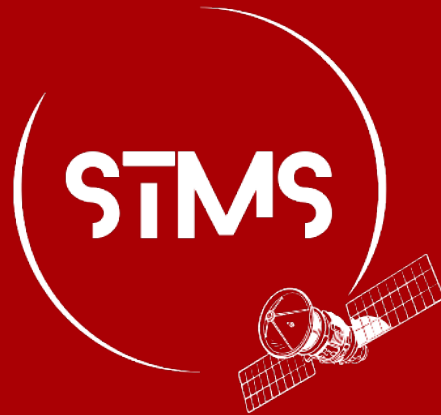
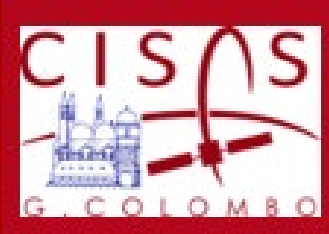
Supervisor: Prof. Daniele Pavarin

Co-Supervisor: Prof. Mirko Magarotto

Admission to the second year - 14/10/2025



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## **Background**

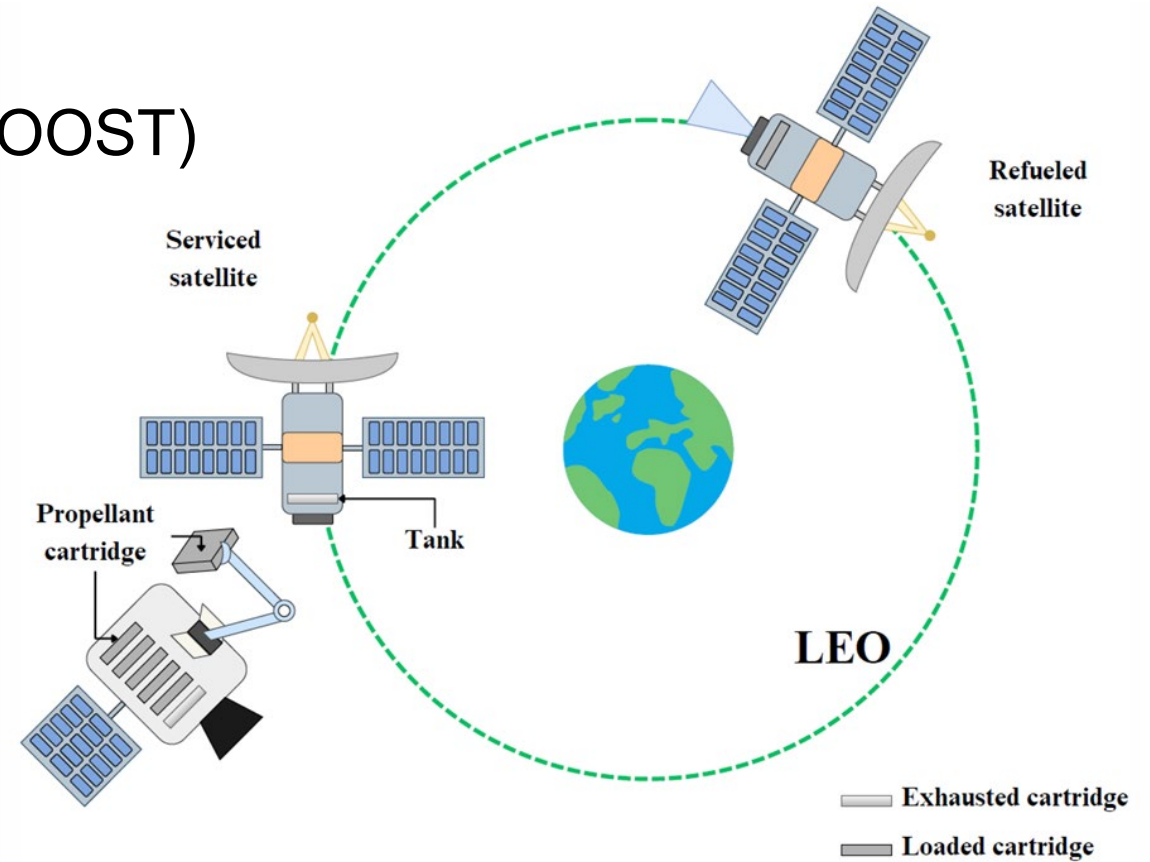
- Project Description
- Research Target
- Research Objective

## Project Name

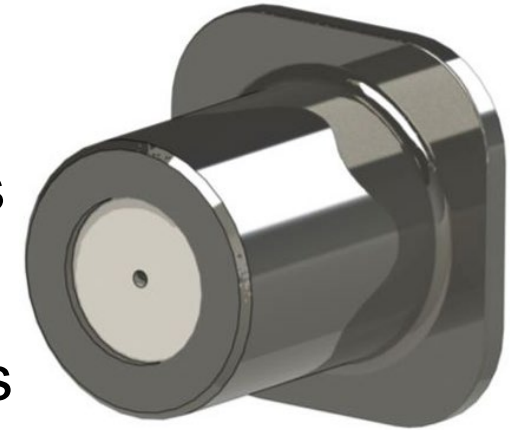
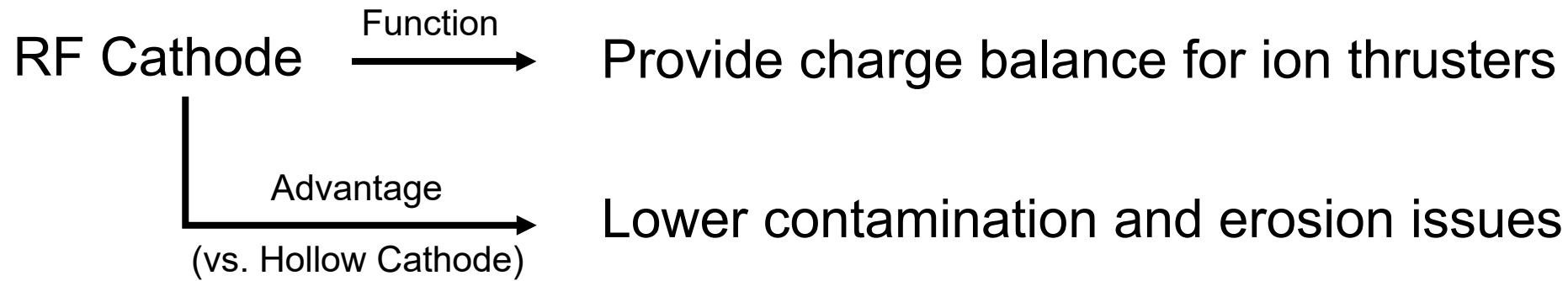
Building BLOcks for IOdine ThruSTers (BOOST)

## Project Ambition

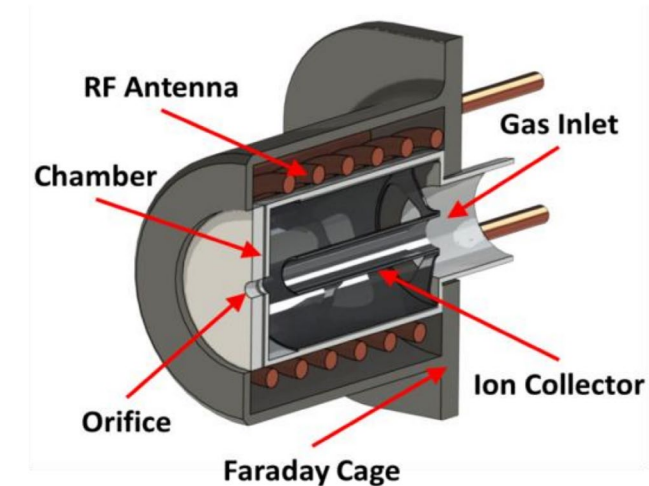
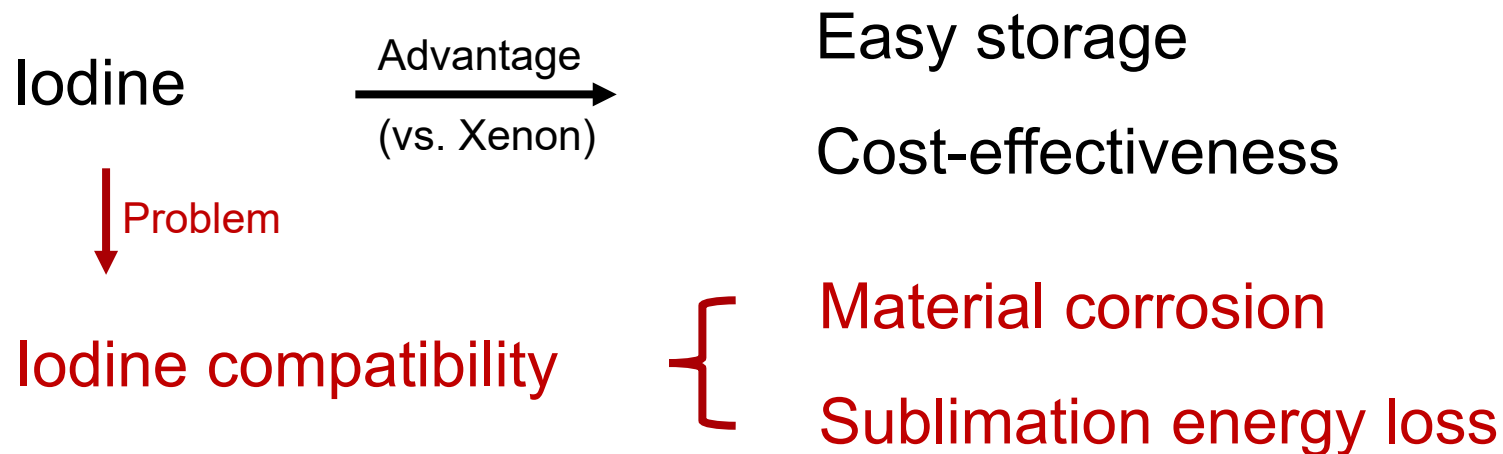
Consolidate and promote the **iodine electric propulsion technology** as a key factor to boost the market of **SmallSats** and the development of future missions of **on-orbit refueling**

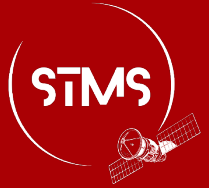
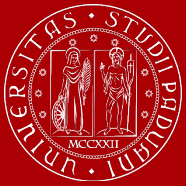


## Research Object



## Research Propellant





## Primary Goal

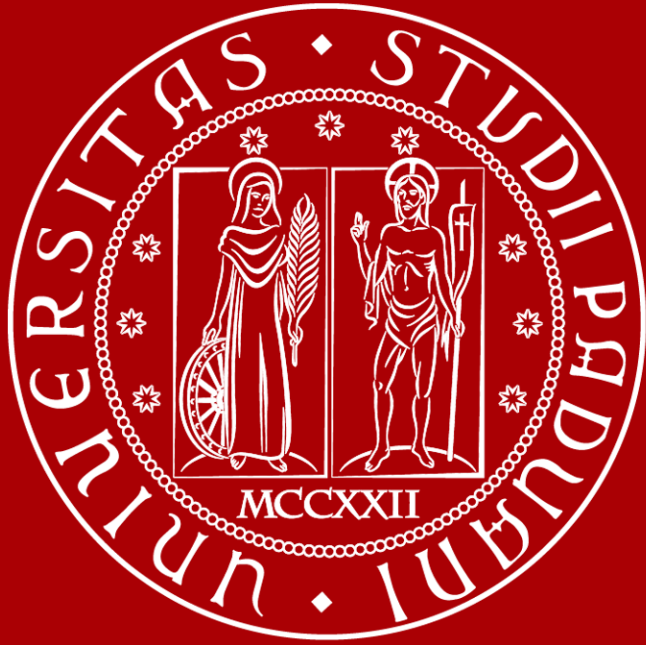
Design and optimize an RF cathode compatible with iodine for small satellites

## Specific Objectives

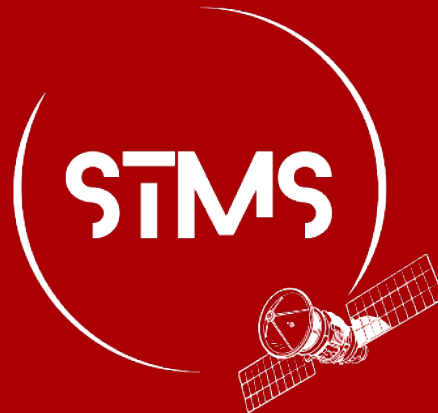
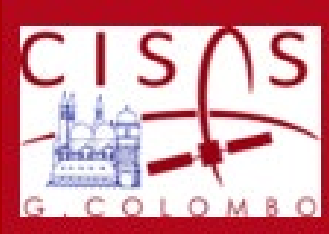
- Model iodine plasma dynamics for better design
- Optimize cathode design for higher ion currents
- Develop iodine-resistant materials

## Expected Results

- New insights into plasma dynamics in iodine-based cathodes
- Scalable design of RF cathodes adaptable to various space missions



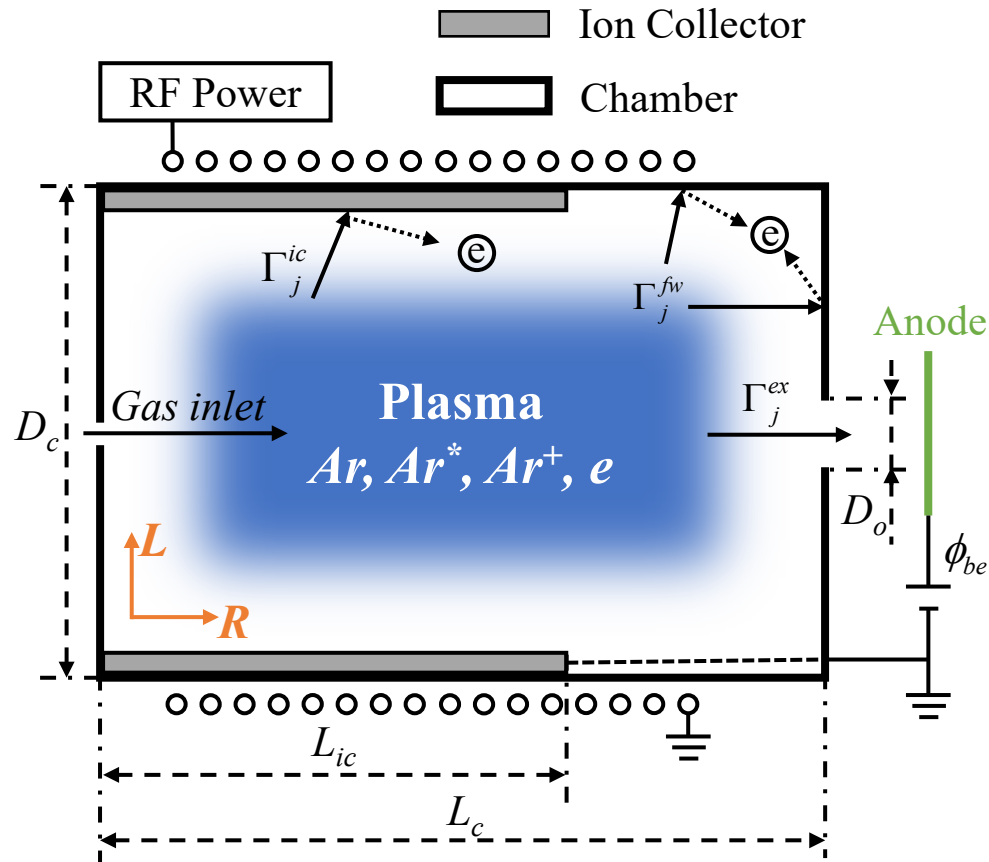
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## **Research content**

- Global Model
- CST Simulation
- Further Research
- Project Timeline

## Model Build



### Governing Equations:

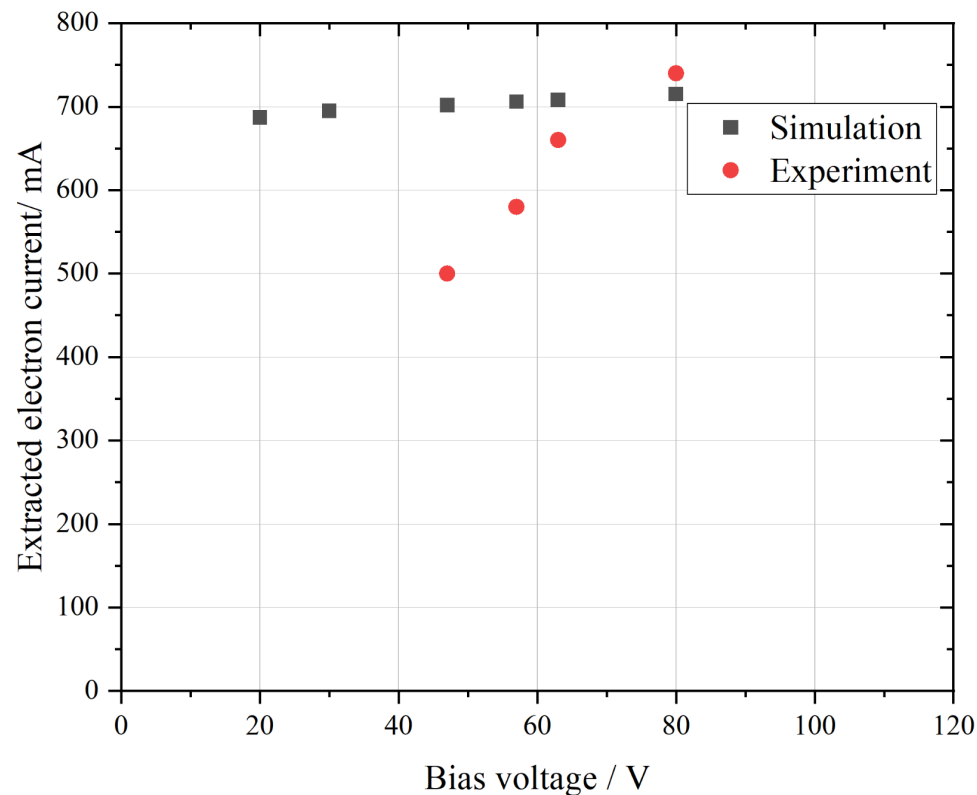
$$\frac{dn_j}{dt} = \dot{n}_j^{react} + \dot{n}_j^{ic} + \dot{n}_j^{fw} + \dot{n}_j^{ex} + \dot{n}_j^{in} \quad (1)$$

$$\frac{d}{dt} \left( \frac{3}{2} n_e T_e \right) = P_{abs} - P_{react} - P_{ic} - P_{fw} - P_{ex} \quad (2)$$

$$\frac{d}{dt} \left( \frac{3}{2} n_0 T_g \right) = P_{gain}^0 - P_{ex}^0 - P_{wall}^0 \quad (3)$$

$$\frac{d}{dt} (CT_w) = P_{wall}^0 - P_{rad} - P_{cond} \quad (4)$$

## Model Validate compared with experiment result in literature[1]

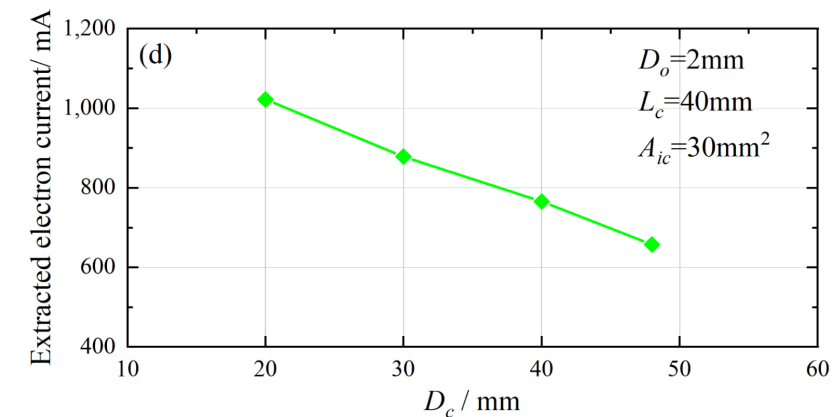
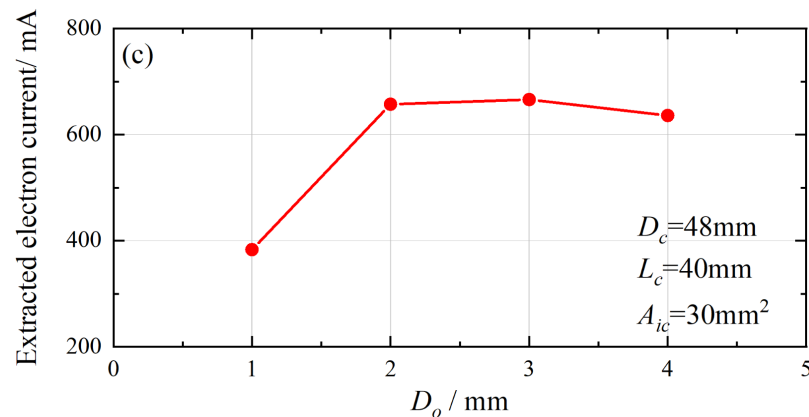
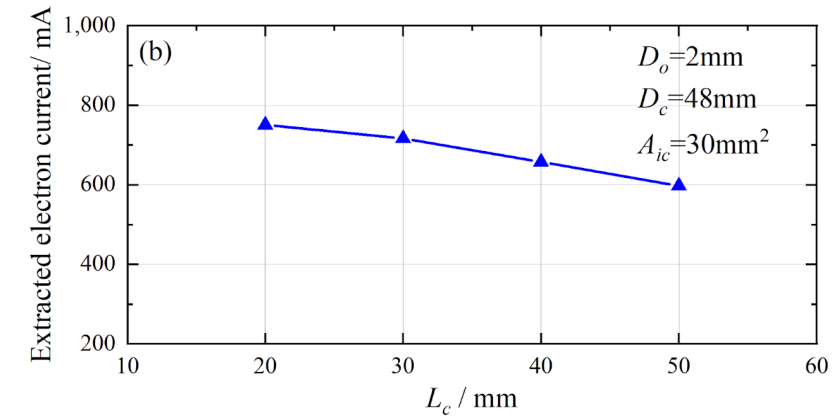
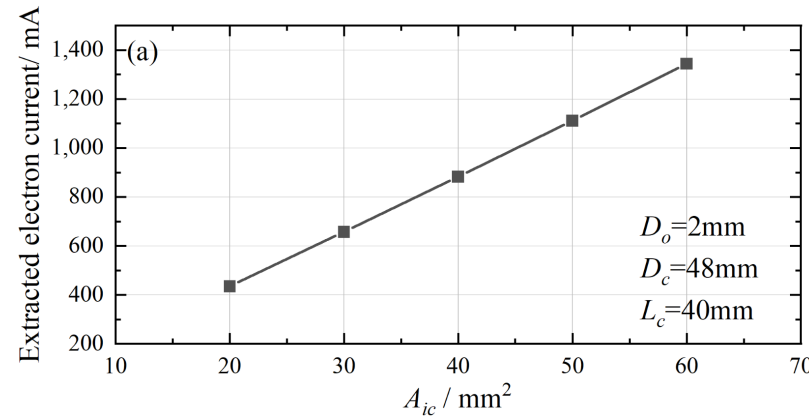


The global model has been exploited for the preliminary design of the cathode

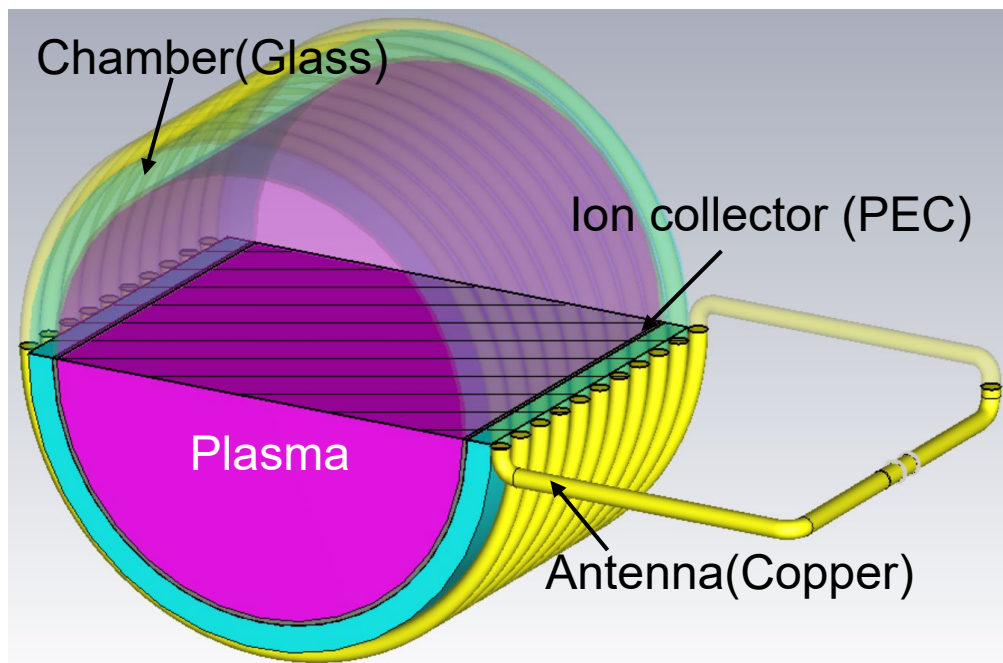
- Definition of optimal dimensions
- Definition of performance trends to be benchmarked against experiments

## Global Model Simulation Result

- The extracted electron current varies linearly with the area of the ion collector. The latter cannot exceed a certain threshold to avoid **screening plasma away from RF power**.
- Large cathode diameters and length cause a drop in the performance due to the reduced **power density** level.
- The orifice diameter has an optimal design parameter, because of the influence of the **plasma sheath**.



## CST Setting

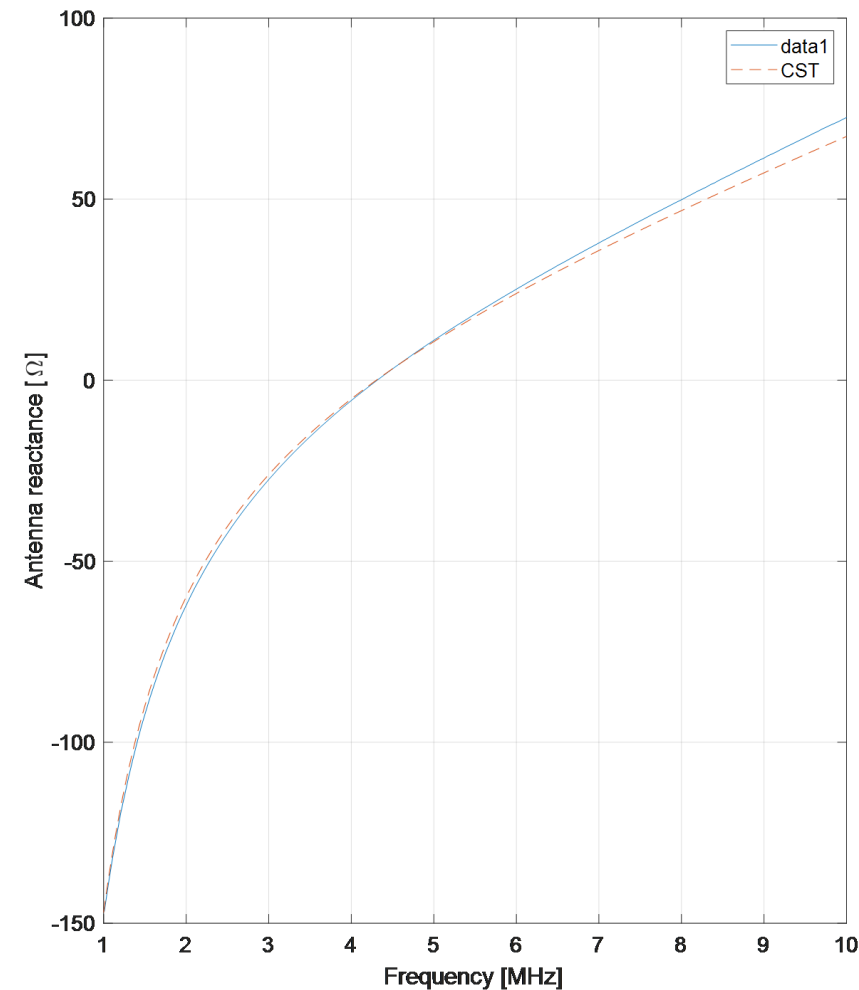


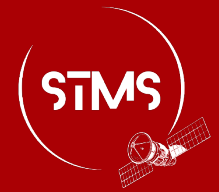
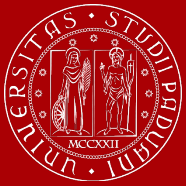
**Antenna - 10 loop series**

**Capacitor - RLC Parallel:**

$$R = 6000 \Omega; L = 1 \text{ mH}; C = 1.05 \text{ nF}$$

**Antenna resistance - Series  $R = 2.35 \Omega$**





## CST Simulation Result

**Goal:** decrease  $\Gamma = \frac{Z_{tot} - 50}{Z_{tot} + 50}$        $Z_{tot} = R_{tot} + X_{tot}i$

**(1) Resonance Frequency** -  $\omega$  when  $X_{tot} = 0$ .

Lowest virtual work loss; **highest couple efficiency** for electromagnetic field

**(2) Real Part Impedance** – Reach  $R_{tot} = 50 \Omega$

Maximize **forward power** delivered to the system

- $q$  and  $P_{rf}$  has mild influence on resonance frequency
- $R_{tot}$  increases with  $q$  and decrease with  $P_{rf}$

Resonance Frequency [MHz]		$P_{rf}$ [W]			
		50	60	70	80
$q$ [sccm]	0.5	7.64	7.67	7.70	7.72
	1	7.70	7.73	7.76	7.78
	1.5	7.73	7.76	7.79	7.81
	2	7.75	7.78	7.81	7.83

$R_{tot} (X_{tot} = 0)$ [ $\Omega$ ]		$P_{rf}$ [W]			
		50	60	70	80
$q$ [sccm]	0.5	15.6	15.3	15.0	14.8
	1	17.7	17.3	16.9	16.5
	1.5	19.0	18.4	18.0	17.5
	2	19.7	19.2	18.7	18.4

## CST Simulation Result

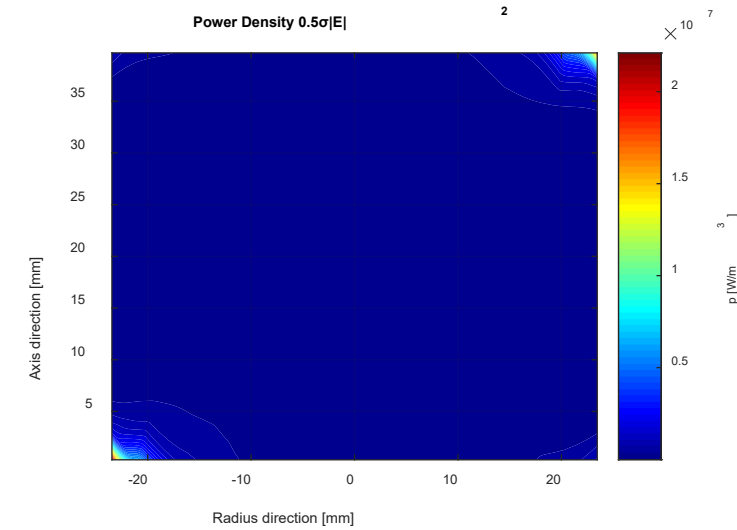
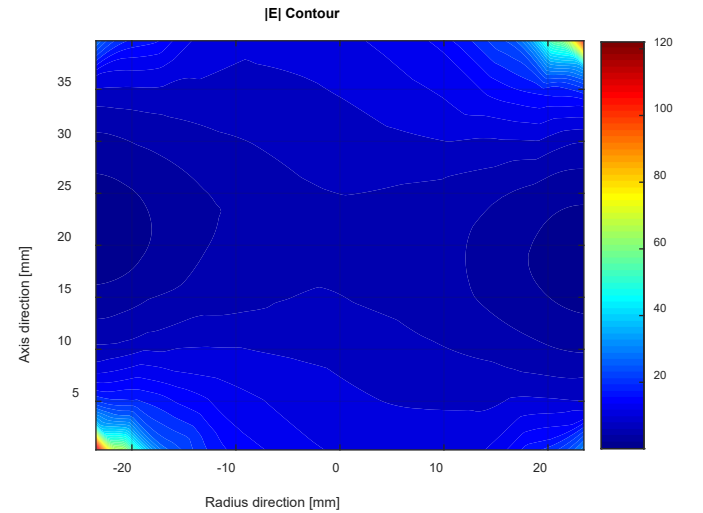
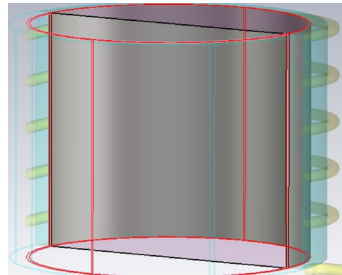
### 5 Loop Antenna

Resonance Frequency:

6.7MHz

$R_{tot}$  :

2.6Ω



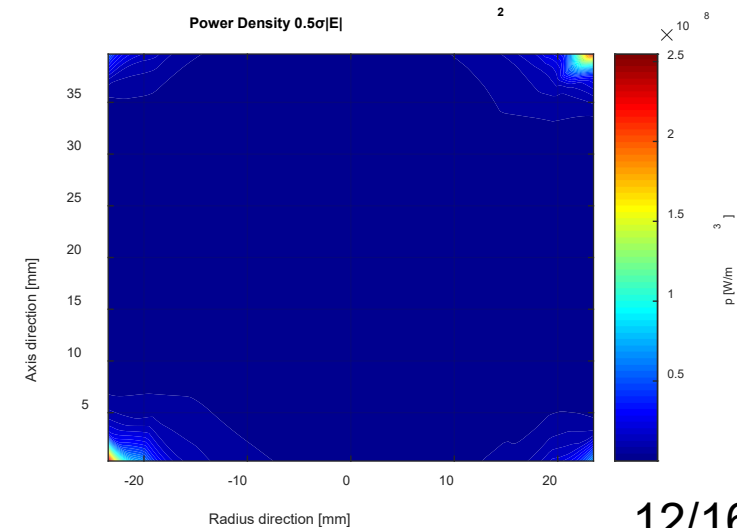
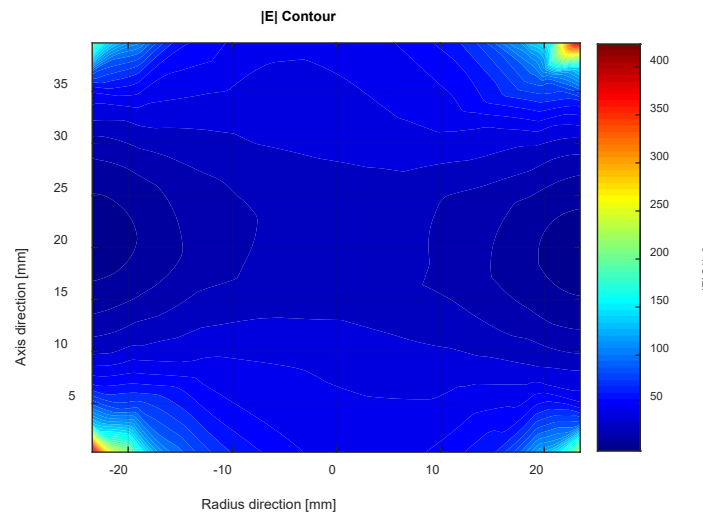
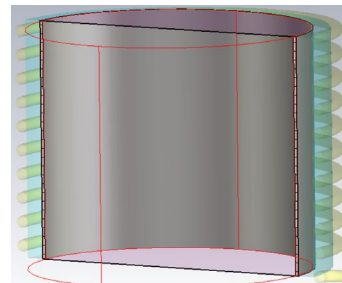
### 10 Loop Antenna

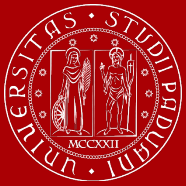
Resonance Frequency:

8.47MHz

$R_{tot}$  :

8.5Ω





## CST Simulation Result

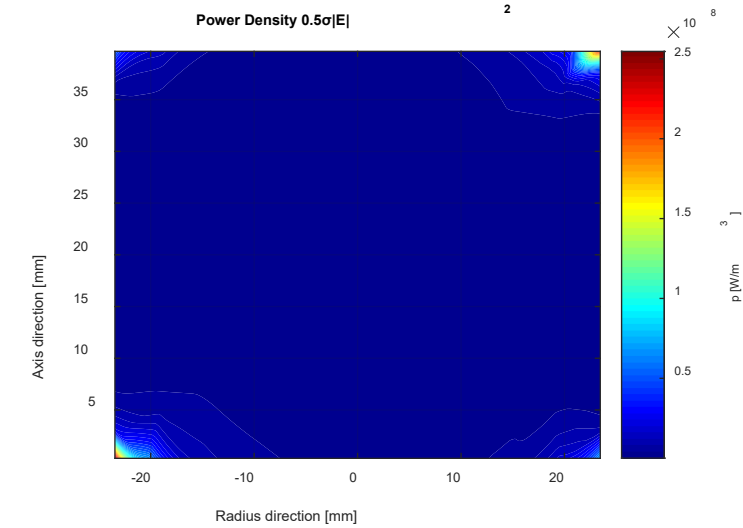
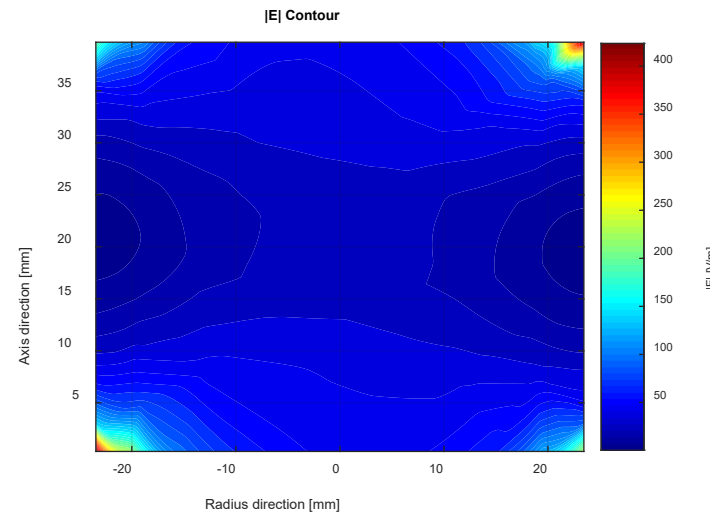
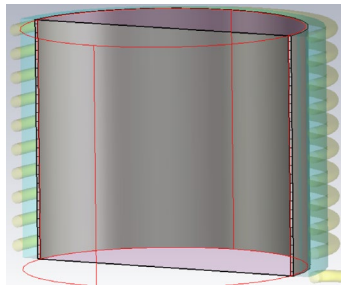
### Full Ion Collector

Resonance Frequency:

8.47MHz

$R_{tot}$  :

8.5Ω



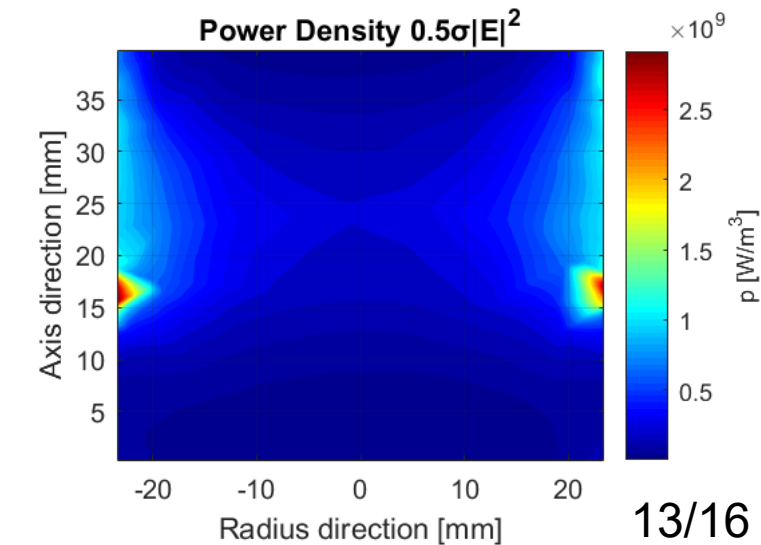
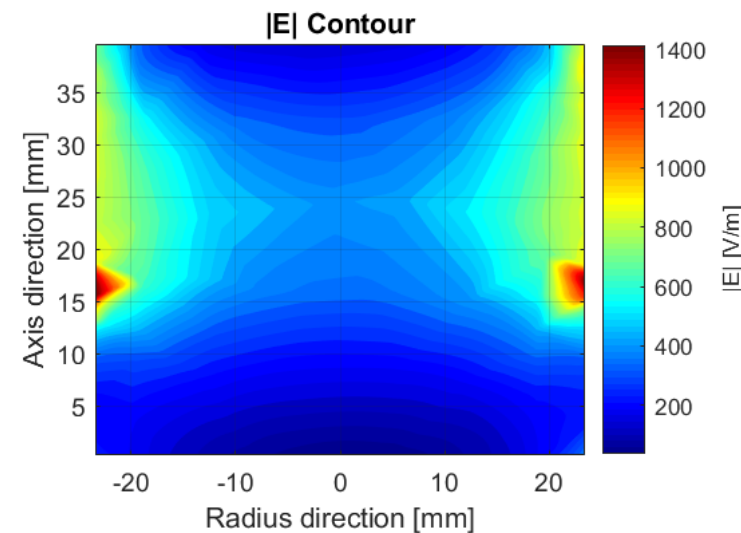
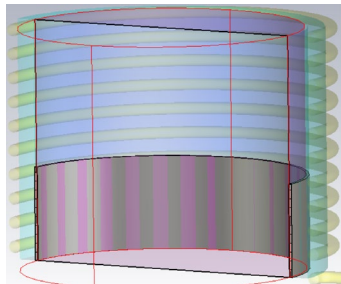
### Shorten Ion Collector

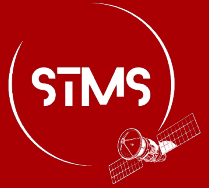
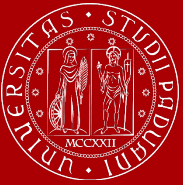
Resonance Frequency:

7.31MHz

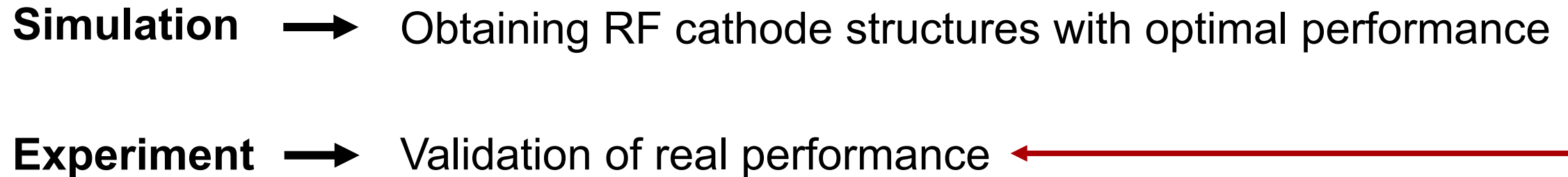
$R_{tot}$  :

10.2Ω





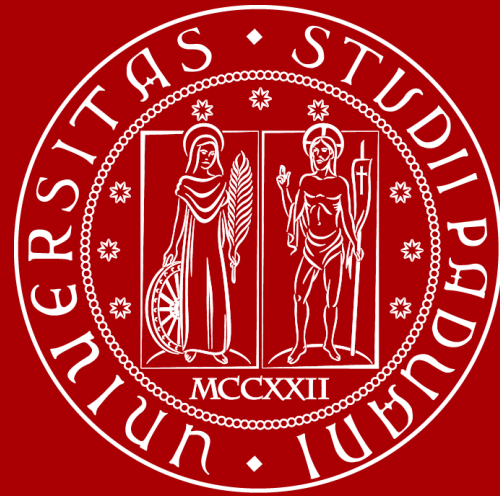
## 3. Optimization and Validation



**4. Final Design** Change cathode for real-world use



Thanks for the attention



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