

# PRELIMINARY ANALYSIS OF THE MAGNETIC ARCH PLASMA IN A CLUSTER OF EPTs

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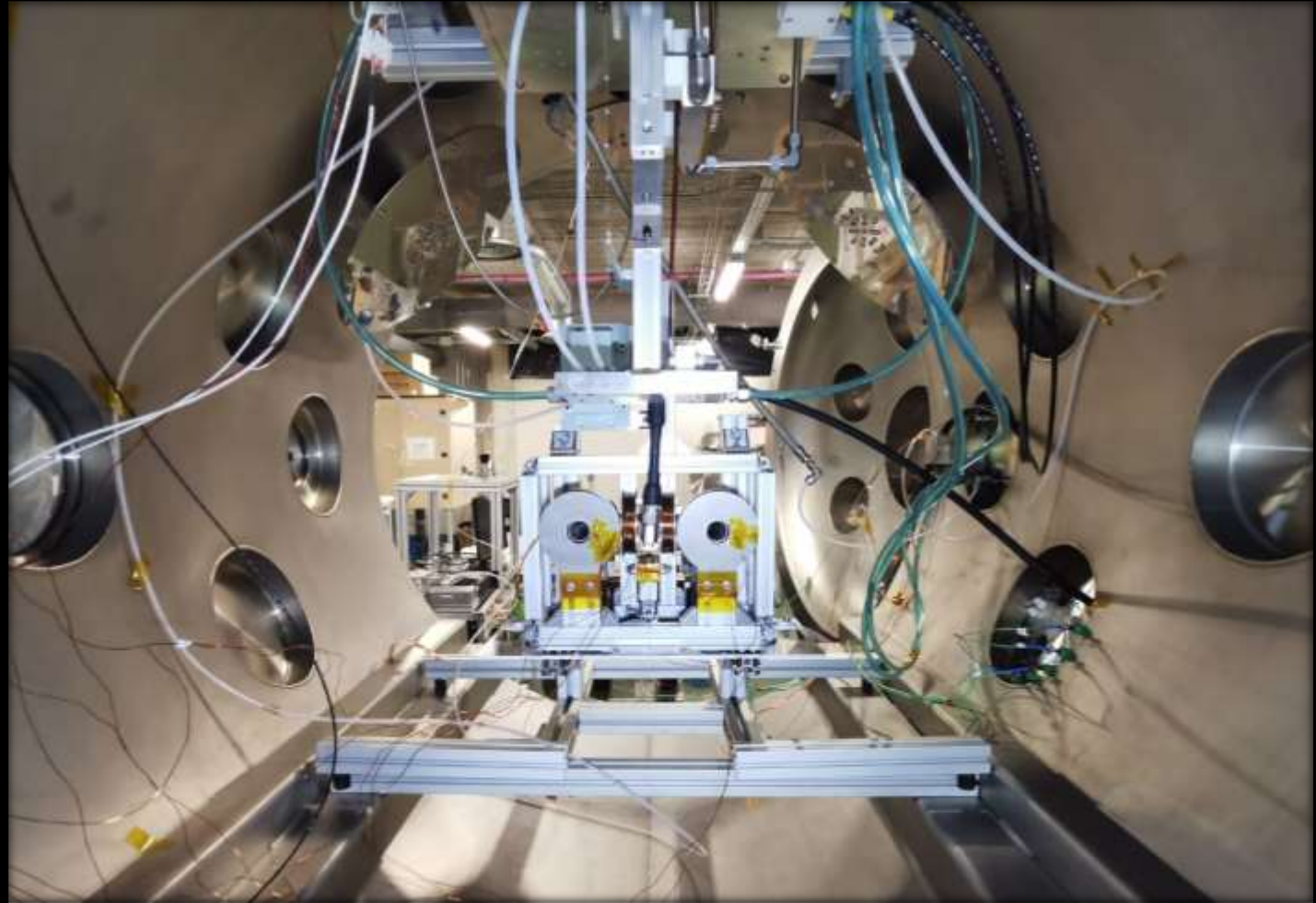
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**EUCASS - CEAS 2023 – 10<sup>th</sup> July 2023**



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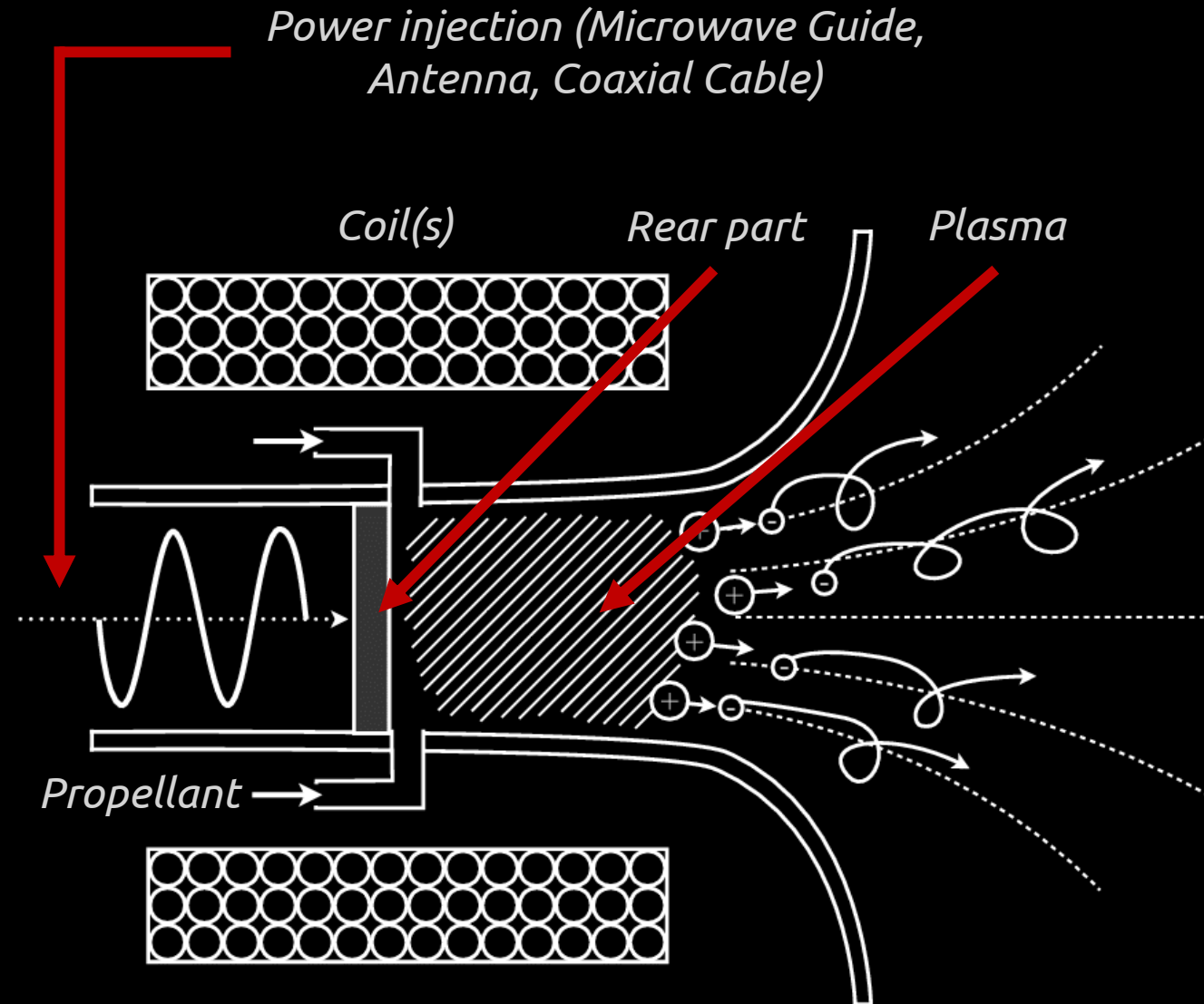


# ZARATHUSTRA MOTIVATION

- **ZARATHUSTRA** thruster focuses on the *Electron-Cyclotron Resonance (ECR) thrusters*.
  - In a magnetic field, electrons have a circular motion due to the *Lorentz* force.
  - When this motion is overlaid by an axial motion, it transforms into a cycloid motion.
  - This cyclotron motion is defined by the strength of the applied magnetic field:

$$f_{ce} = \frac{e B}{2\pi m_e}$$

- Plasma generation is enabled by collisions between electrons and neutrals.

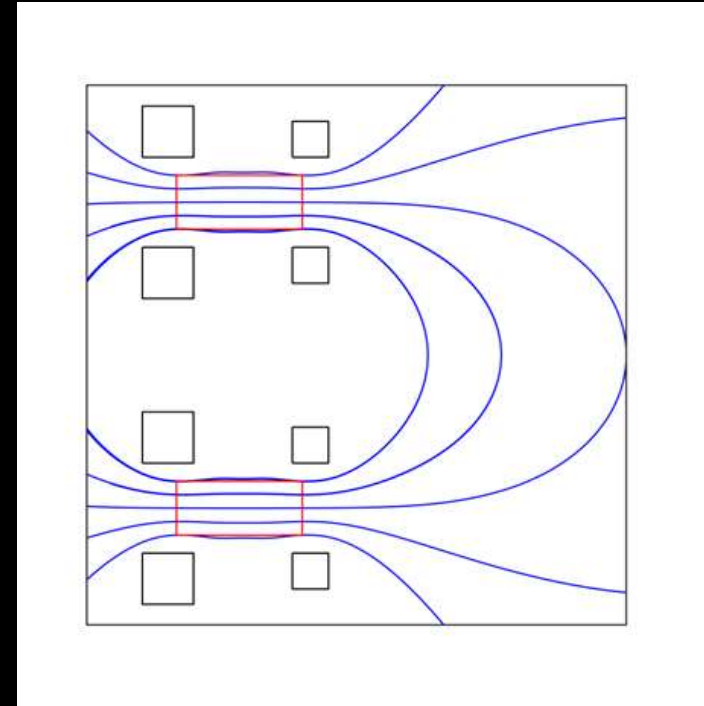


# ZARATHUSTRA MOTIVATION



Cluster being assembled

- Classic *EPTs* acts like total magnetic dipoles, coupling with the Earth's magnetic field and therefore producing secular torque.
- The cluster is a dual coaxial *ECR* thruster (a) developing a magnetic arch with a closed-line topology.
- Interaction in between two *ECR* sources enables:
  - Closed-line magnetic field topology.
  - Lowering of the plume divergence.





# CLUSTER ARCHITECTURE

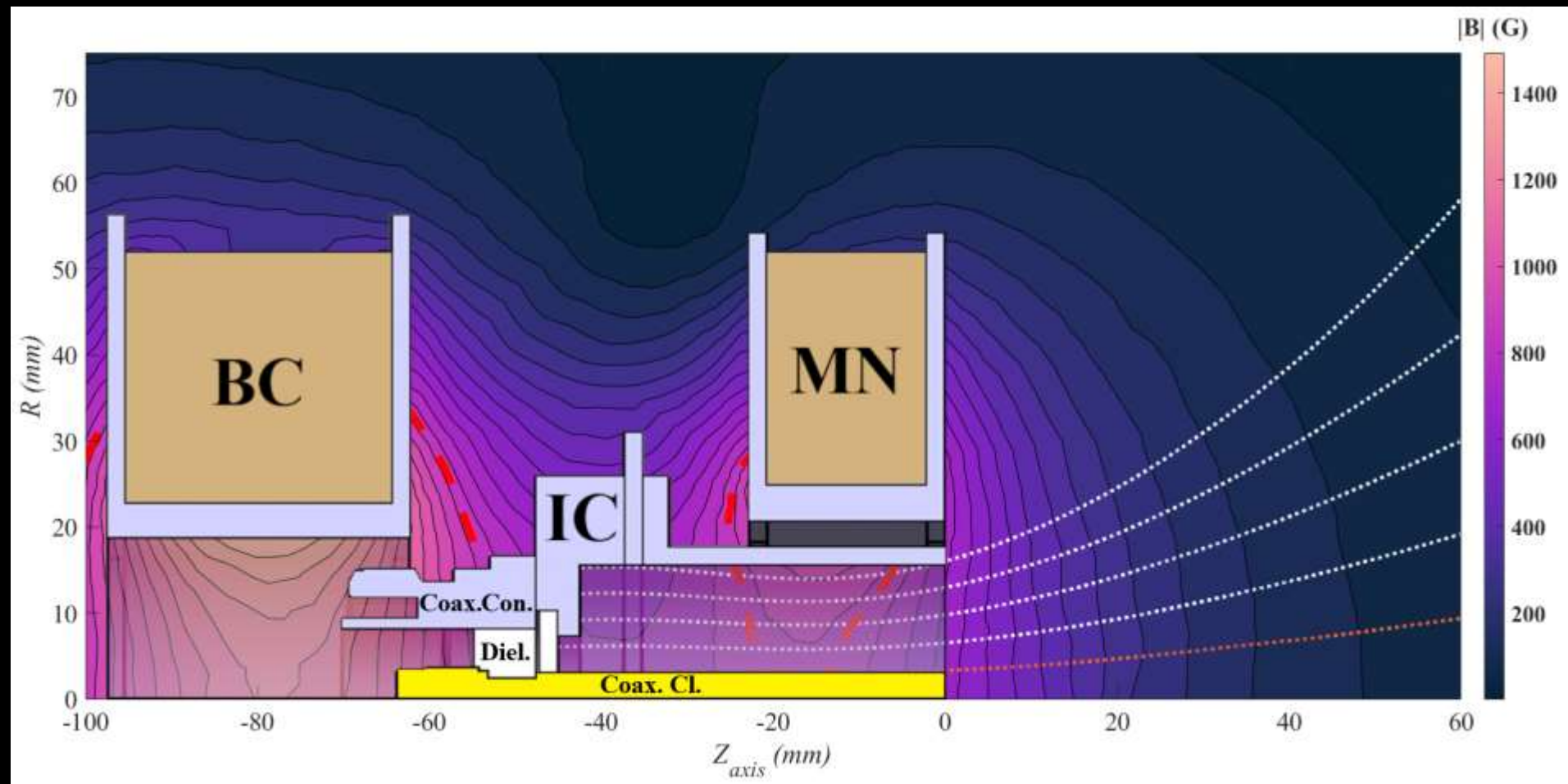
## Electromagnets

Maximum total power per source 1 kW

Maximum magnetic field intensity 1480 G

ECR resonance field 875 G

Total number of turns per source  $\approx 1200$



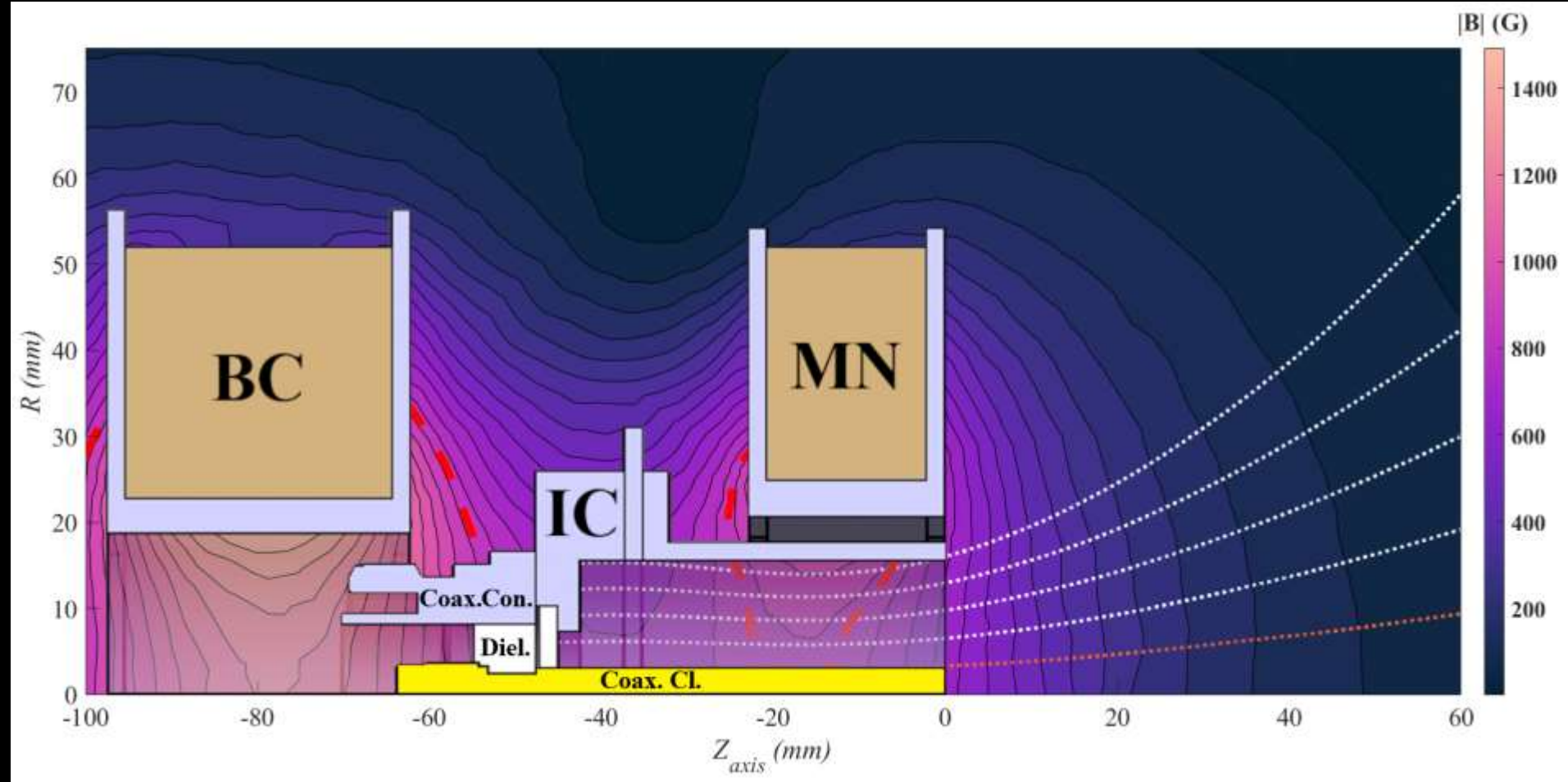
# CLUSTER ARCHITECTURE

## Ionisation chamber

Length 43.73 mm

Diameter 30 mm

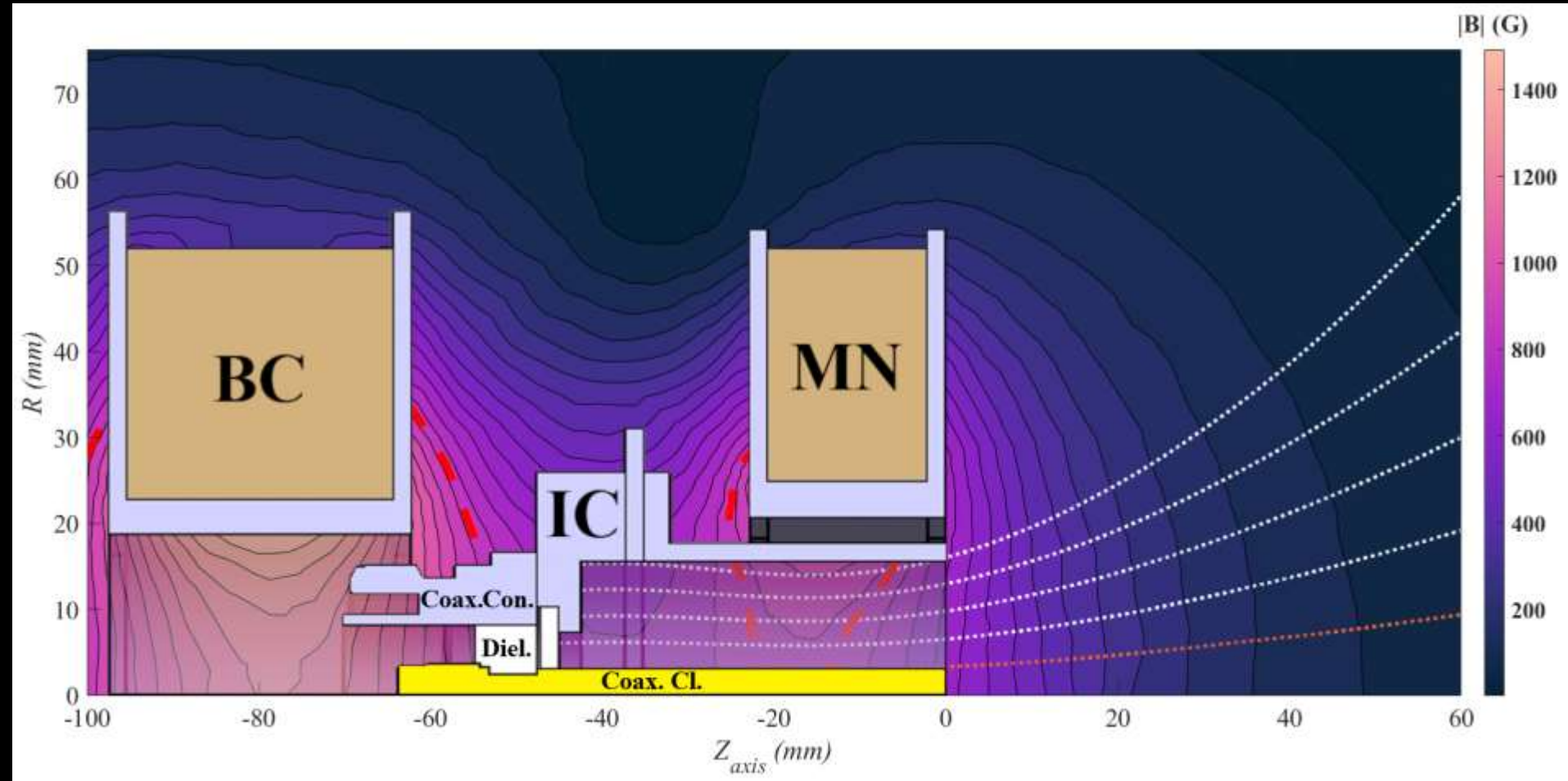
Material Non-magnetic Stainless Steel



# CLUSTER ARCHITECTURE

## Gas feeding

Gas	Krypton
Ignition mass flow rate	50 sccm
Operation mass flow rate	15 sccm

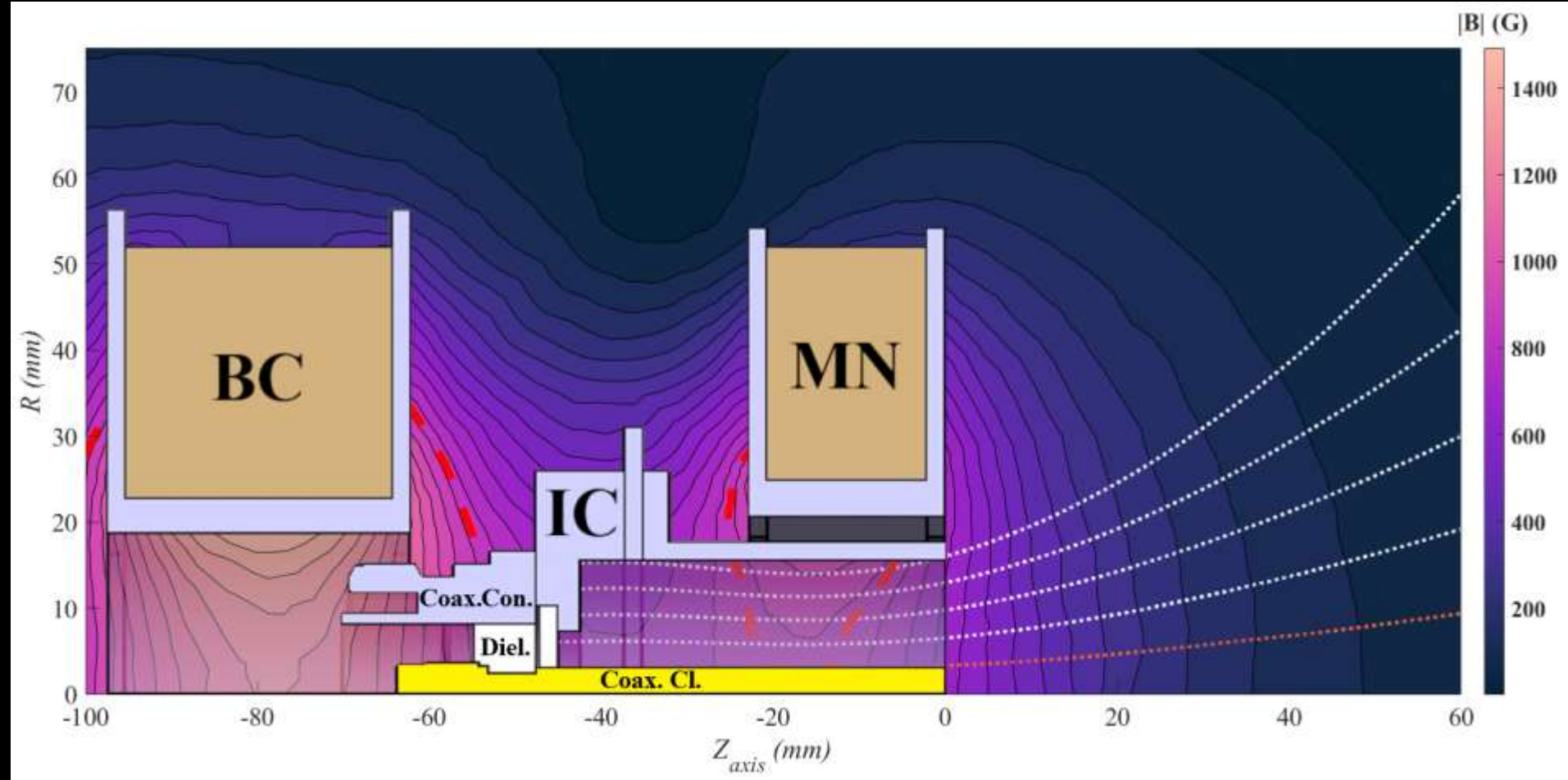




# CLUSTER ARCHITECTURE

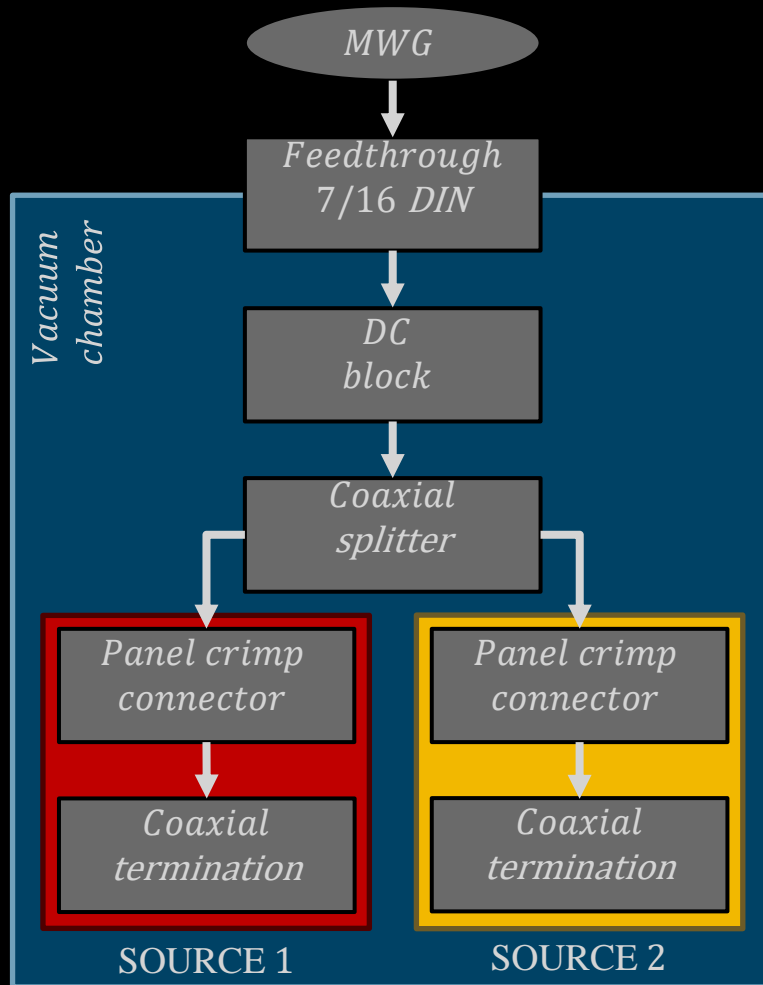
## Coaxial cylinder

Length	50 mm
Diameter	6 mm
Frequency	2.45 GHz
Power	50 W–500 W





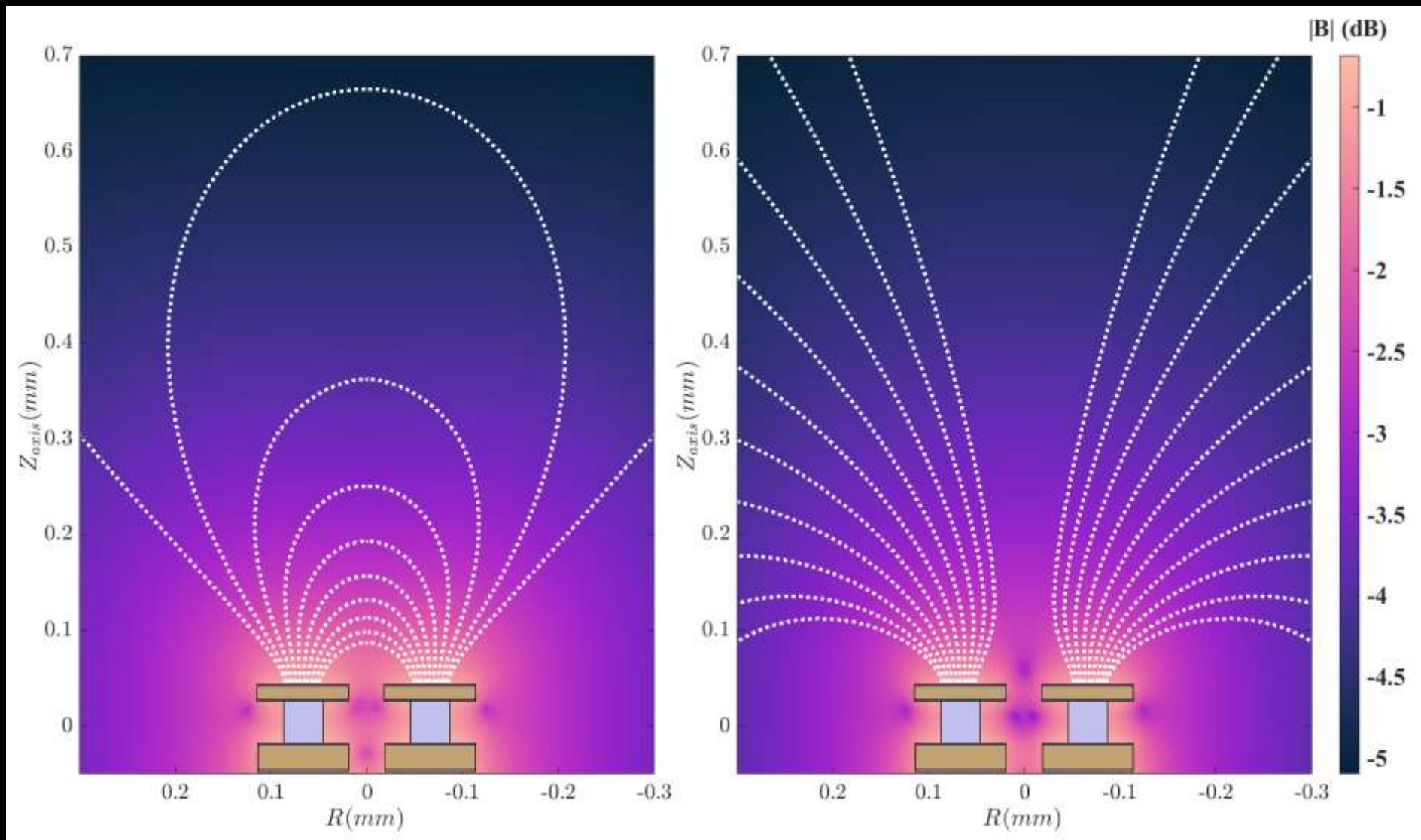
# CLUSTER ARCHITECTURE



- 2.45GHz tunable ( $\pm 50$  MHz) solid state microwave generator (**Muegge** MR1000D-200ML).
- 7-16 DIN coaxial 2.45 GHz graded feedthrough (**Allectra** 242-7\_16-K50).
- Coaxial 2.45GHz graded all females three ways splitter (**Microlab** D2-16FD).
- M3 termination 7-16 DIN panel crimp (**Telegartner** J01121A0721).
- Elements connected with coaxial cables:
  - LMR-600-FR coaxial cables
  - TC-600-716M-X coaxial connectors.

# EXPERIMENTAL SETUP

Magnetic field  
with "MF  
ARCH"  
configuration.



Magnetic field  
with "MF  
SAME"  
configuration.

# EXPERIMENTAL SETUP



Cluster thruster installed in the EP2 group vacuum chamber

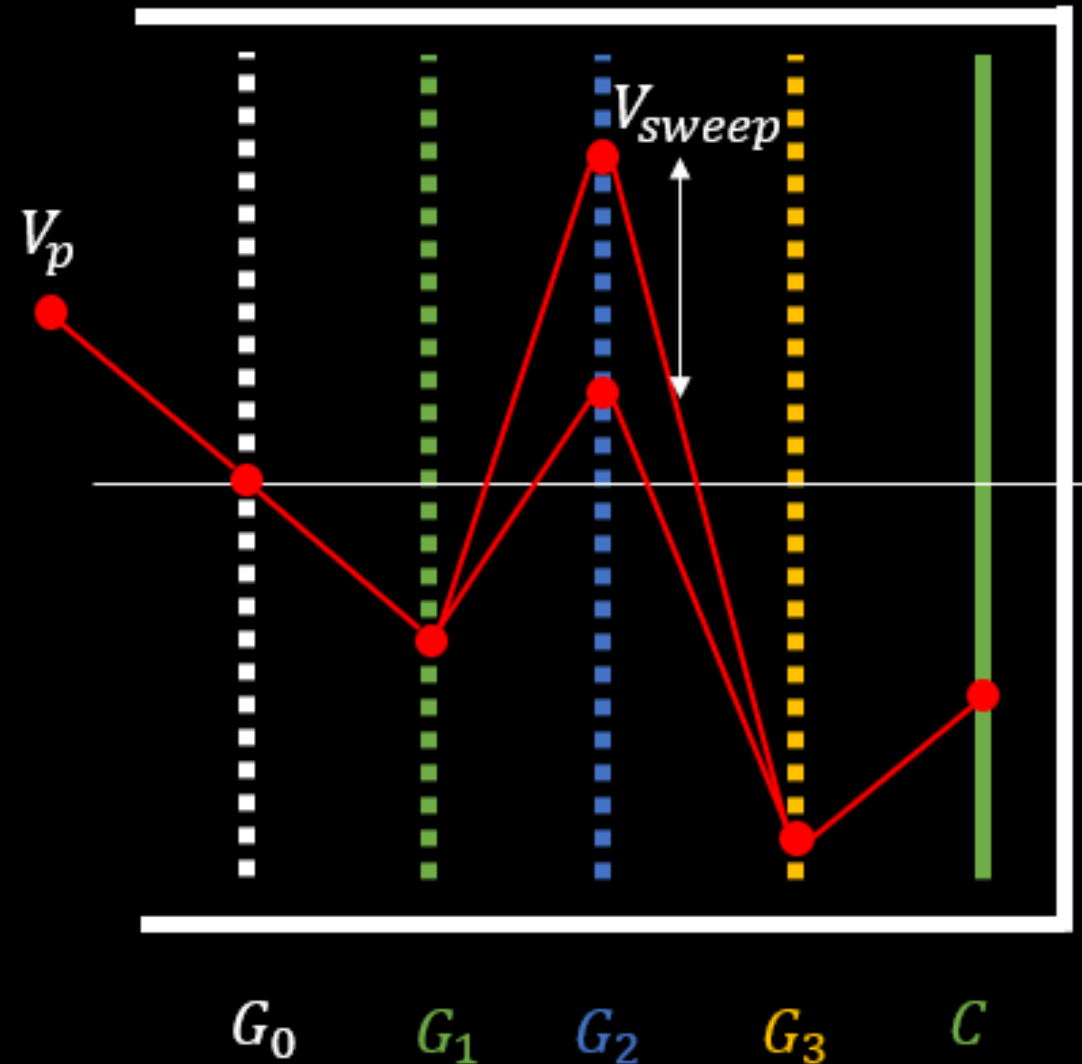
- Technology in use:

- Primary pump: Leybold **Leyvac LV 80** ( $80 \text{ m}^3/\text{h}$ )
- Turbomolecular pumps: 2 **MAGW2.200iP** ( $2000 \text{ l/s}$ )
- Cryopanels: 3 Leybold **Leyvac 140 T-V**
- Leak detector: Leybold **L300i**

<i>Vacuum chamber characteristics</i>	
Length	3.5m
Diameter	1.5m
Operational pressure	$2e - 5 \text{ mbar}$ at $20 \text{ sccm}$ of $Xe$
Pumping speed	$> 37000 \text{ l/s}$ of $Xe$

# EXPERIMENTAL SETUP - RPA

- Radial / Polar positioning system used in the vacuum chamber with a *Retarded Potential Analyzer (RPA)*.
- **RPA** characteristics:
  - Distance to the thruster: 380mm
  - Number of holes per grid: 37
  - Ion collection area:  $A = 1.86e - 5 \text{ m}^2$
  - Transmission factor:  $T = 0.0625$
  - Set of angles:  $[-50^\circ, -25^\circ: 5^\circ: 25^\circ, 50^\circ]$
  - $IEDF, \bar{E}_i, \bar{v}_i, I_{Tot}$





# EXPERIMENTAL SETUP - RPA



Cluster in operation with "MF ARCH" configuration.

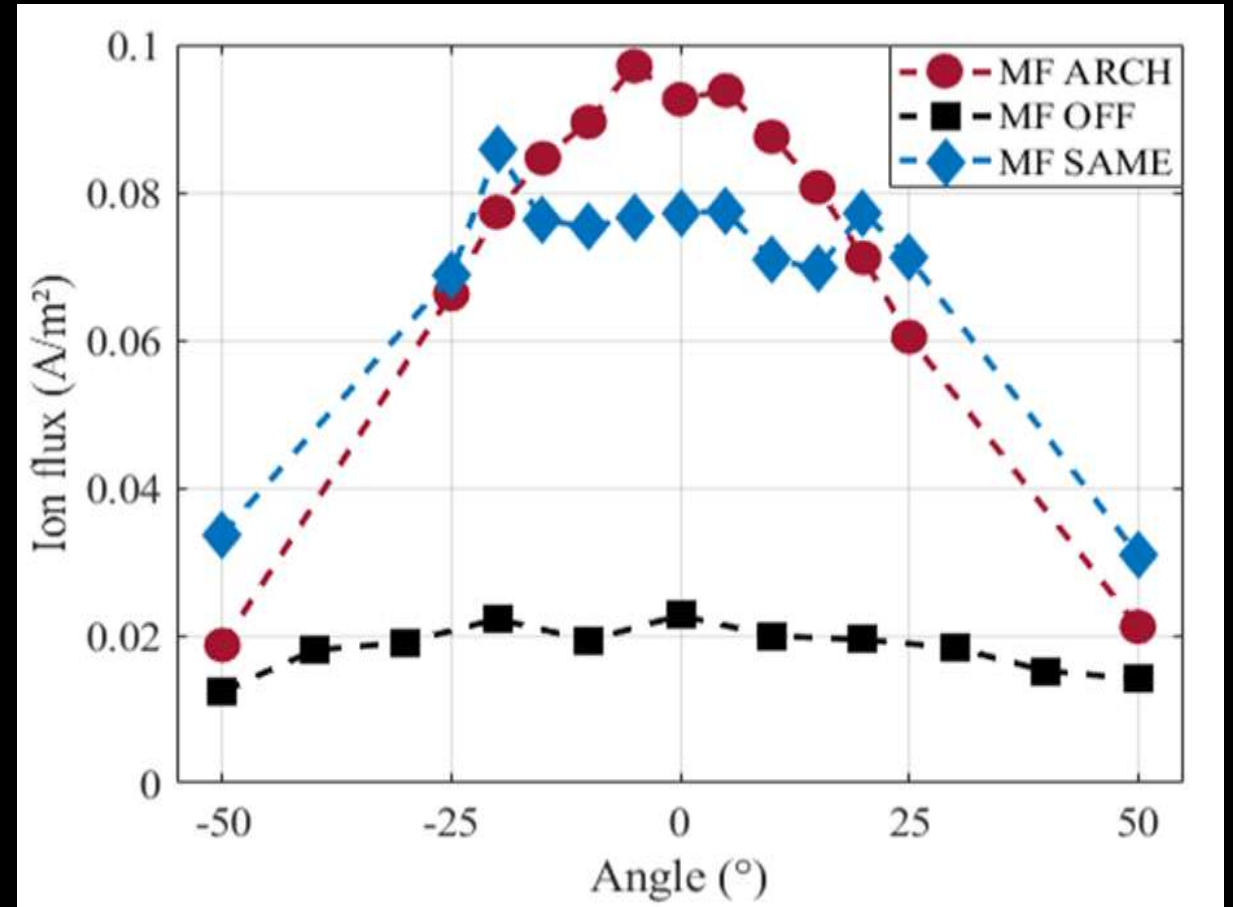


Cluster in operation with "MF SAME" configuration.

15 sccm of Krypton, 100 W at 2.45 GHz

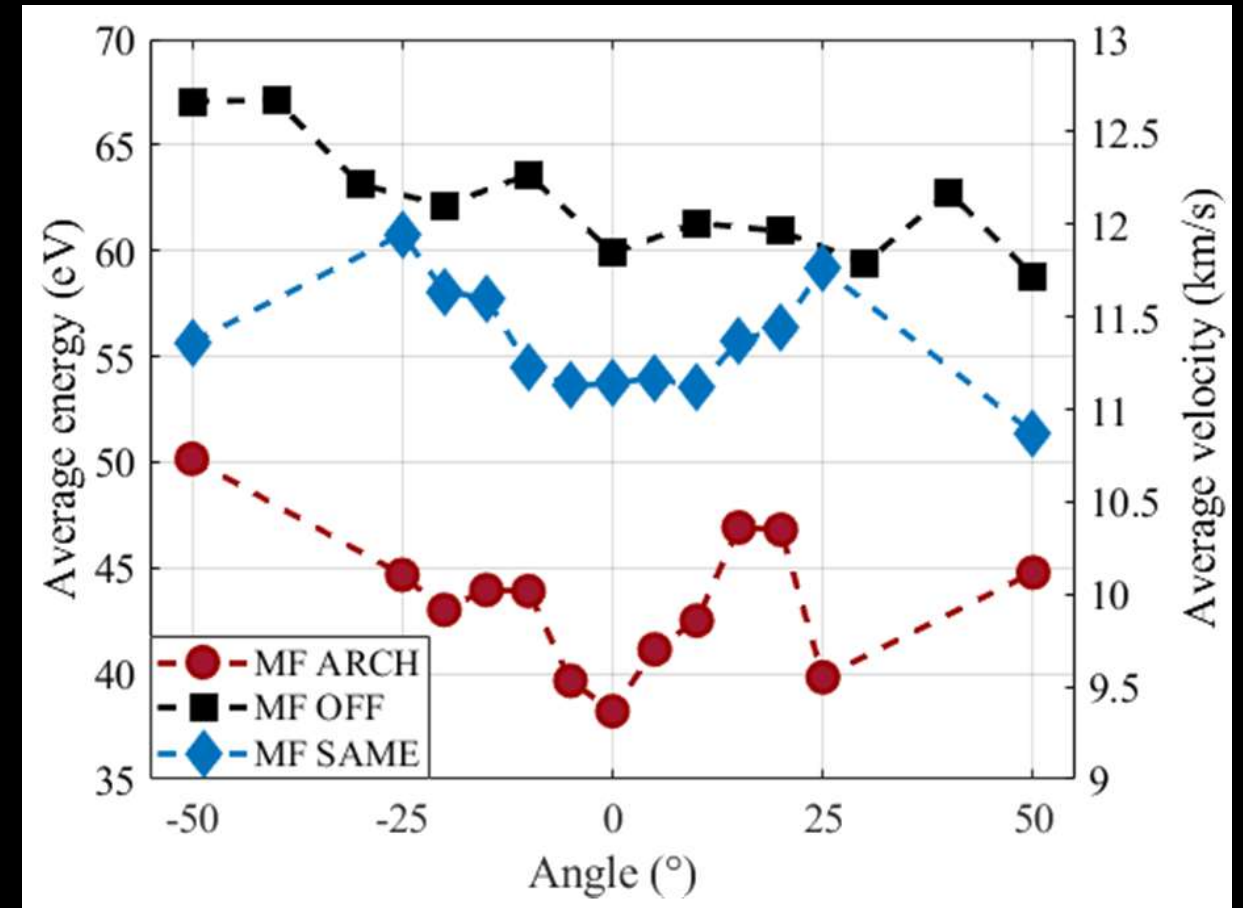
# RESULTS - ION FLUX

- Plasma is extracted from the closed-line magnetic topology, with less divergence than the other topologies.
- *MF SAME* ion flux plot symmetry is coherent with the corresponding magnetic topology.
- *MF OFF* ion flux plot lies one order of magnitude lower than the other magnetic topologies.

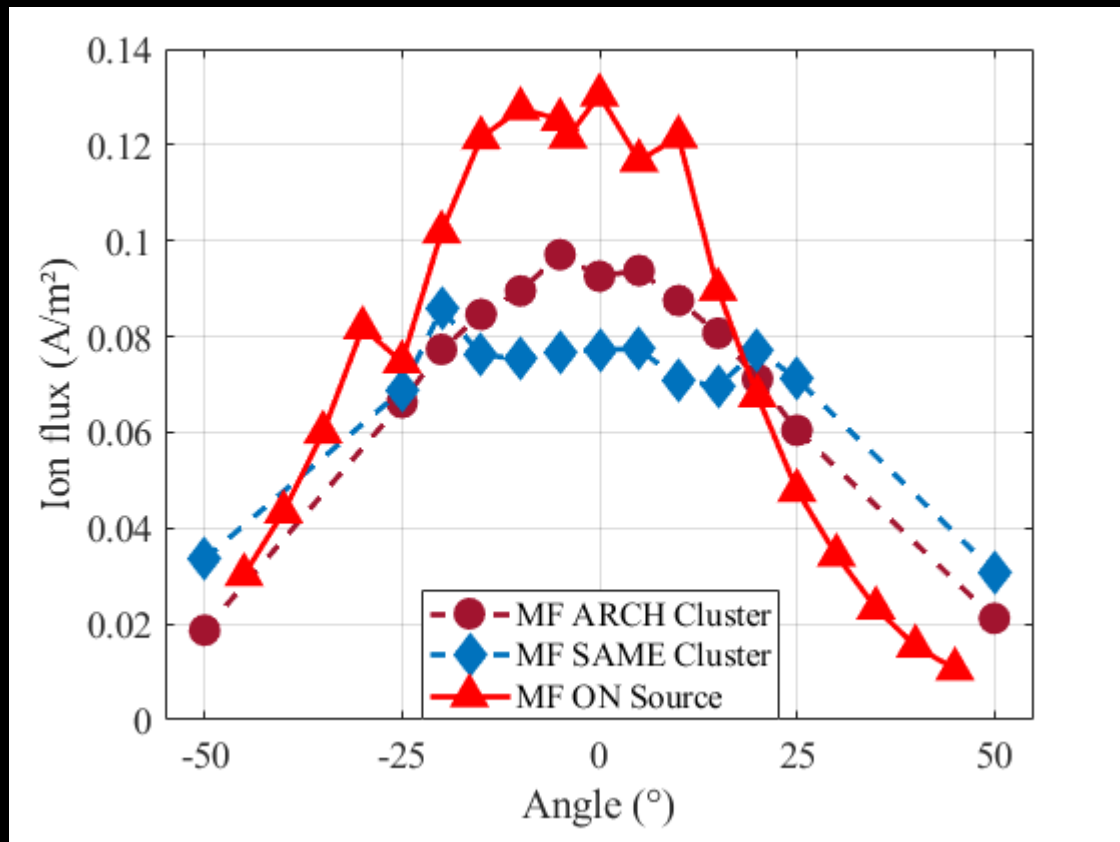


# RESULTS - AVERAGE ION ENERGY AND VELOCITY

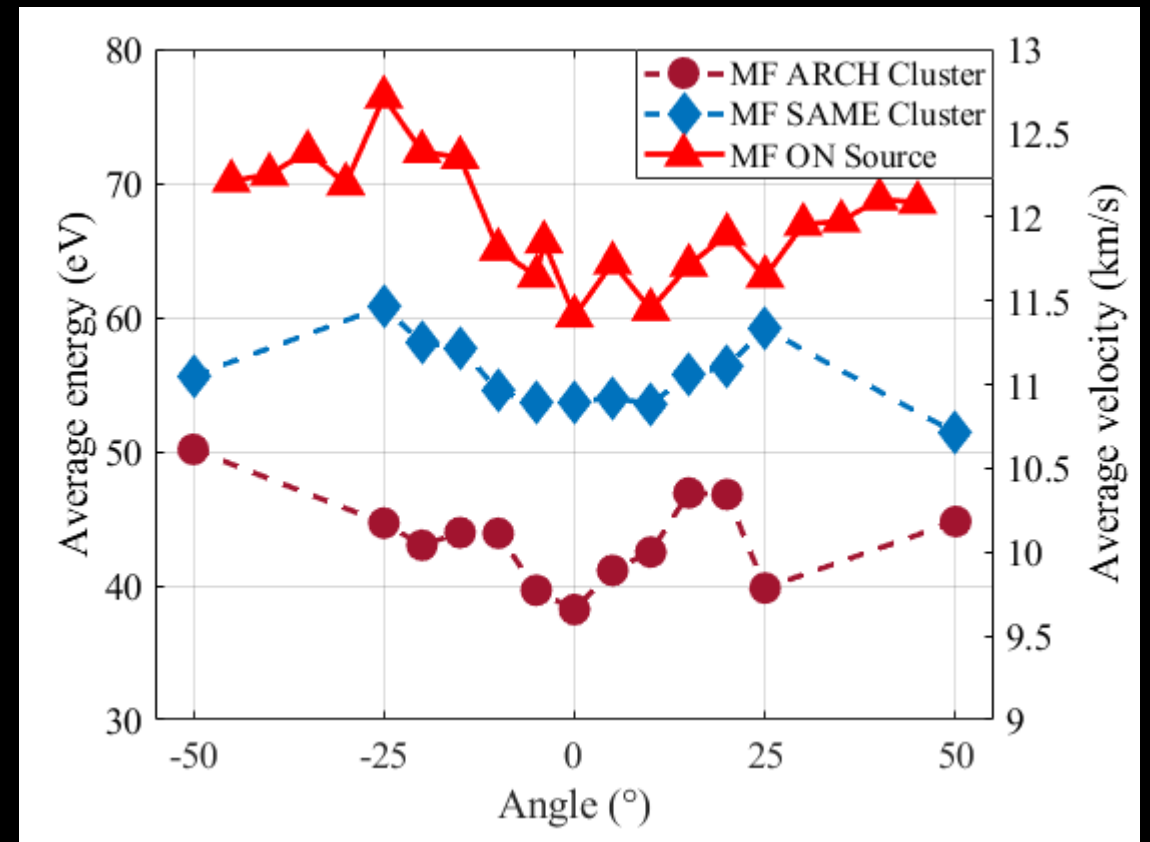
- Lowest average energy for *MF ARCH*.
- Closed-line magnetic field might prevent the acceleration of ions close to  $0^\circ$ .
- Measured ion average energy is directed in the perpendicular direction to the RPA.
- Differences in between the ion flux and the average energy plots could indicate the need to improve the probing setup.



# RESULTS - ONE SOURCE THRUSTER COMPARISON



Comparison of the ion flux in between one and two sources.



Comparison of the average energy and velocity in between one and two sources.



# CONCLUSION

- First dual EPT thruster to be ignited and run with different magnetic topologies.
- A decrease in divergence is reached with the *MF ARCH* topology, confirming previous simulation works.
- Presence of a magnetic field arch does not prevent plasma expansion nor ions acceleration.
  
- Plasma characteristics in between single and dual sources are comparable and lead to the need of a deeper study into the magnetic arch.
- Closed-line magnetic field thruster concept is compatible with in-space application to counter secular torque.
  
- Improved diagnostics are needed to measure accurately the plasma characteristics for *MF MARCH* topology.
- Power absorption / coupling need to be studied and measured to determine the real coupling efficiency regarding both the magnetic field topology and the thruster dimensions.
- Better definition of functioning points is needed in terms of mass flow rate and power.

# THANK YOU!



# ACKNOWLEDGMENTS

This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 950466)

