COMSOL CONFERENCE
2017 ROTTERDAM

Copper Electrochemical Polishing Optimisation

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Outline

- Introduction to CERN
- Motivation of the work
- Electrochemical simulations
- Fluid dynamic simulations
- Summary

Introduction to CERN

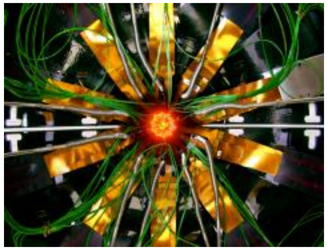
CERN, is the world's largest particle physics centre and home to the Large Hadron Collider (LHC).

The mission

- Answer fundamental questions about the Universe.

  E.g. How did the universe begin? What is the nature of dark matter?

- Develop new technologies for accelerators and detectors.



- Bring nations together and train the scientists and engineers of tomorrow.

  22 member states, just over 2500 staff members, over 12000 scientists, more than 100 nationalities.

Introduction to CERN

The research tools of CERN are the accelerators where the particles are made to collide.

Large Hadron Collider (LHC)

- World's most powerful accelerator.
- A ring of 27 km circumference.
- LHC collision energy: 14 TeV.

Future Circular Collider (FCC) study

- Develops different scenarios for high energy circular colliders for **post LHC era.**
- Ring of 80 - 100 Km
- FCC collision energy: 100 TeV.

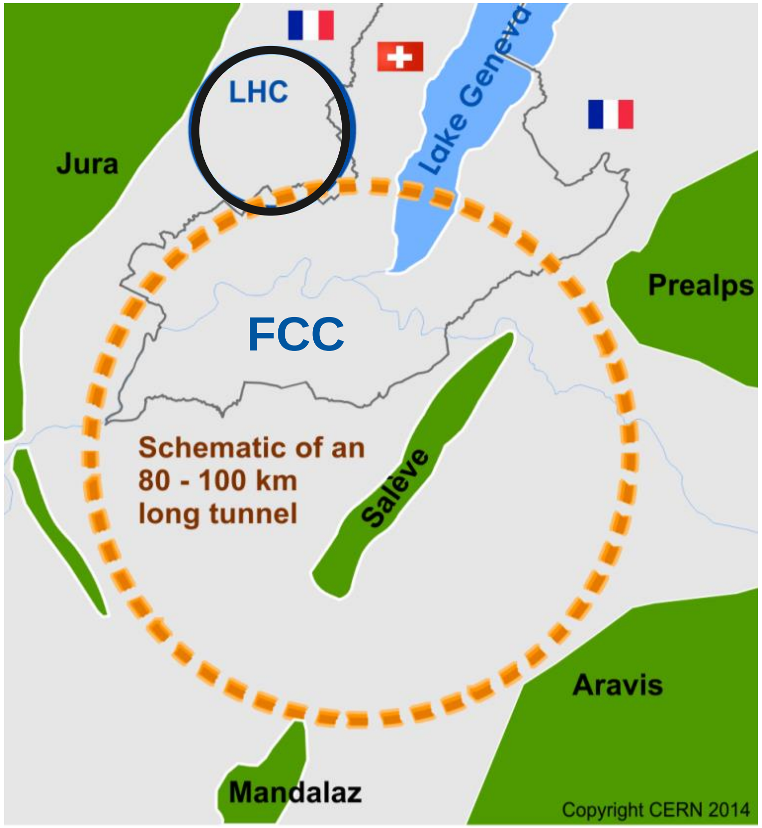


Image of the Future Circular Collider

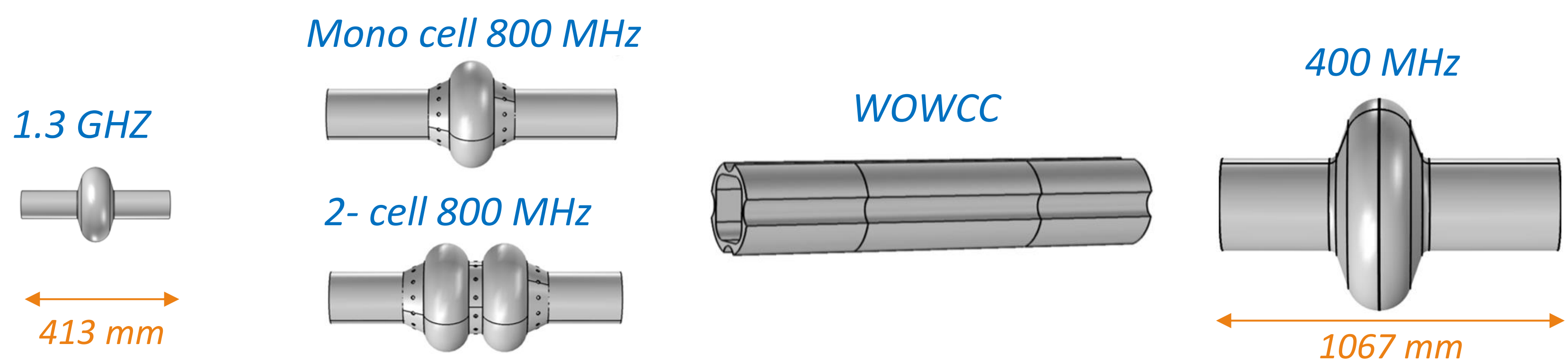
Motivation

The superconducting radiofrequency (SRF) accelerating powered cavities are necessary to accelerate the particles.

This work should:

- Supply data in order to define the best SRF scenario for the Future Circular Collider.
- Provide the possibility to process cavities with the best technological process available (Electropolishing) to fulfil particle acceleration requirements.

Copper electropolishing (EP) installation



Motivation

Requirements of the new facility

- Compatible with 1.3 GHz to 400 MHz copper cavities.
- Enable horizontal and vertical processing.
- Uniform polishing on complex geometry.

400 MHz cavity

COMSOL MULTIPHYSICS® → Definition of the working variables

Easy assessment of the parameters for the different scenarios.

Optimisation of the process

Electrochemical simulations

Objective

- Identify working parameters.
- Define optimum cathode geometry

→

Min. power input

Even current density along cavity surface = uniform polishing

Electron transfer reactions of copper EP:

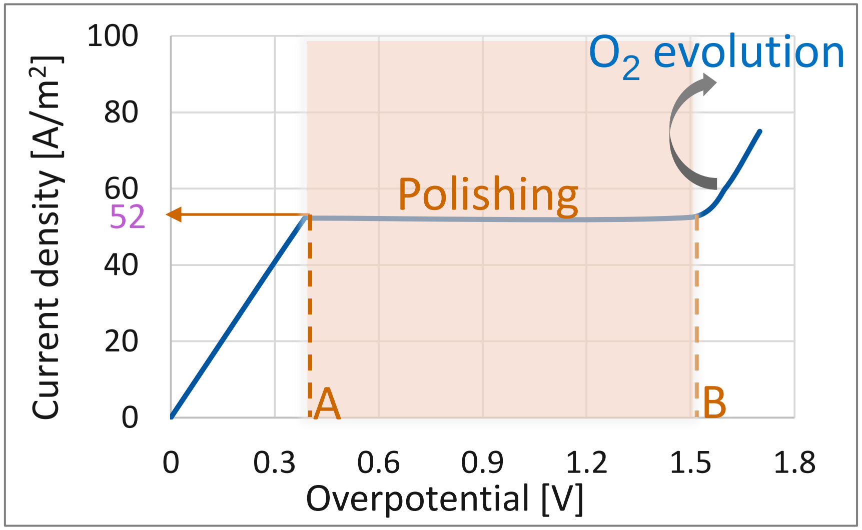
- Anode (cavity surface)

  $Cu \rightarrow Cu^{2+} + 2e-$

  $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

- Cathode

  $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

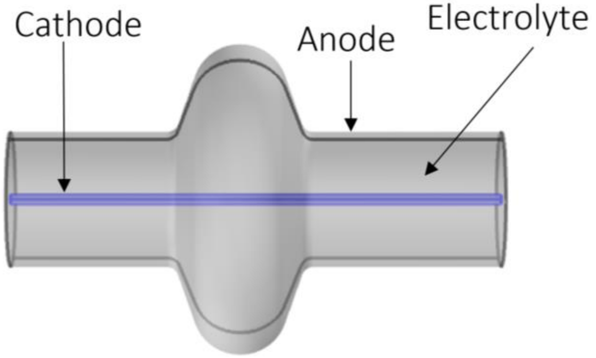


Anodic polarisation curve of the copper bath (15 degrees and 100 rpm).

Electrochemical simulations

Model construction

- Goal: Simulate the current density distribution in the 400 MHz cavity.
- Physics module: Secondary current distribution (SCD).
- Type of study: Stationary.



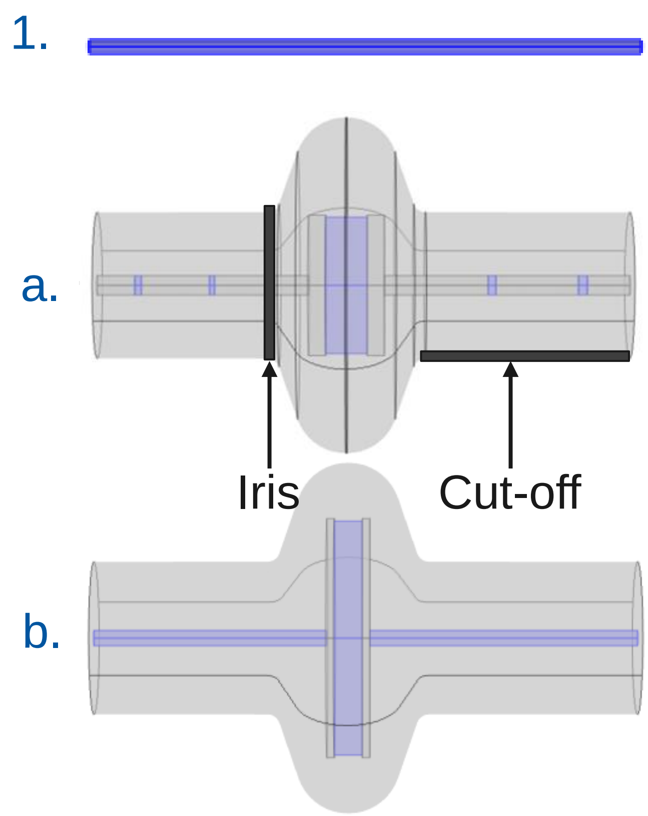
Model defined

- Boundary conditions:
  - ➢ Cathode surface: ϕs, ext. = 0 V.
  - ➢ Anode surface: ϕs, ext. = Ecell.
  - ➢ Electrodes kinetics defined using polarisation curves.

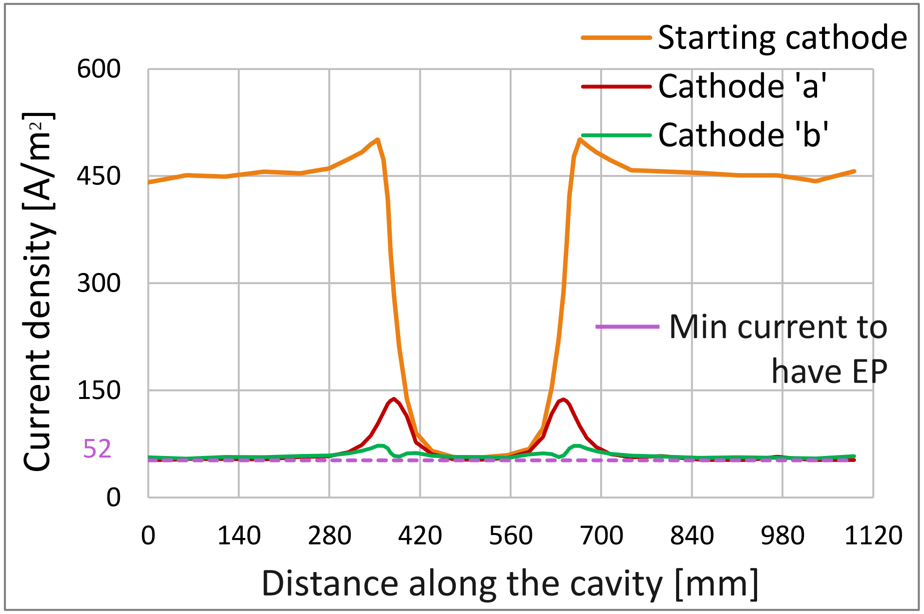
Electrochemical simulations

Results

Cathode geometries defined:



Output electrochemical simulations:

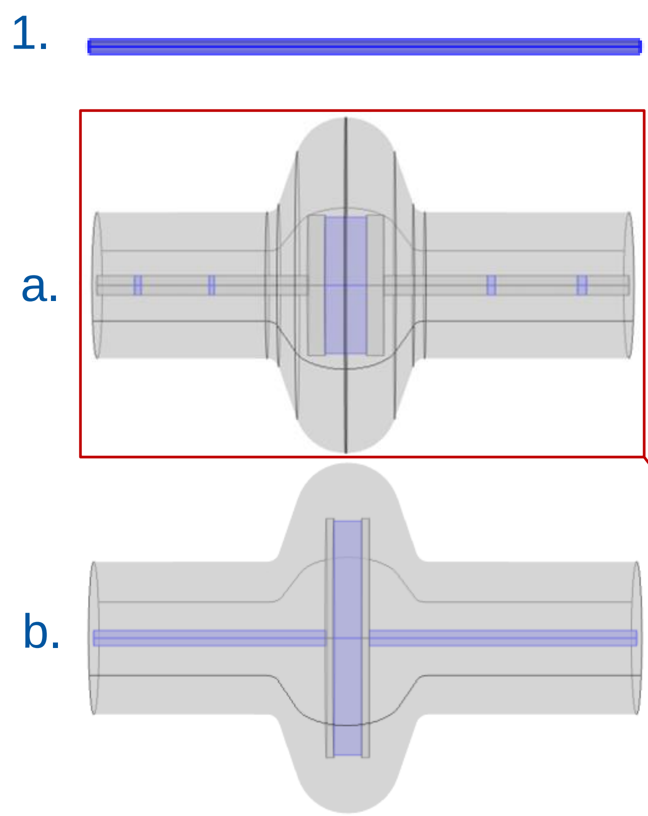


	Min. working potential [V]
Starting Cathode	65
Cathode 'a'	18
Cathode 'b'	8

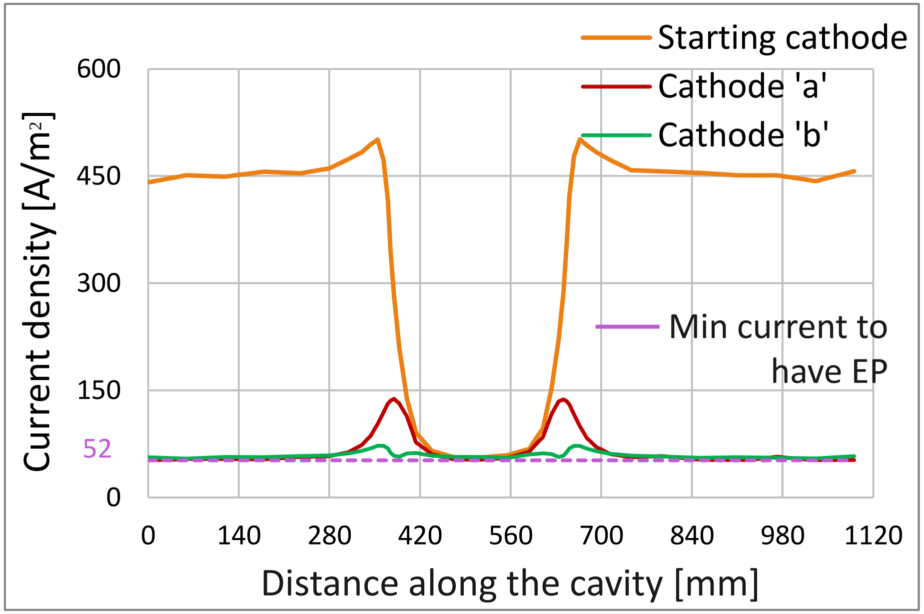
Electrochemical simulations

Results

Cathode geometries defined:



Output electrochemical simulations:



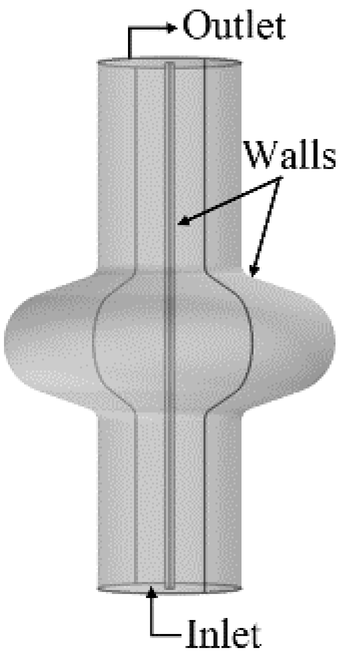
Total current [A]	Min. working potential [V]
135	18

Next step: Fluid Dynamic simulations

Objective

- Improvement of the cathode shape in terms of homogeneous electrolyte velocity distribution near the cavity wall.

Model construction



Model defined

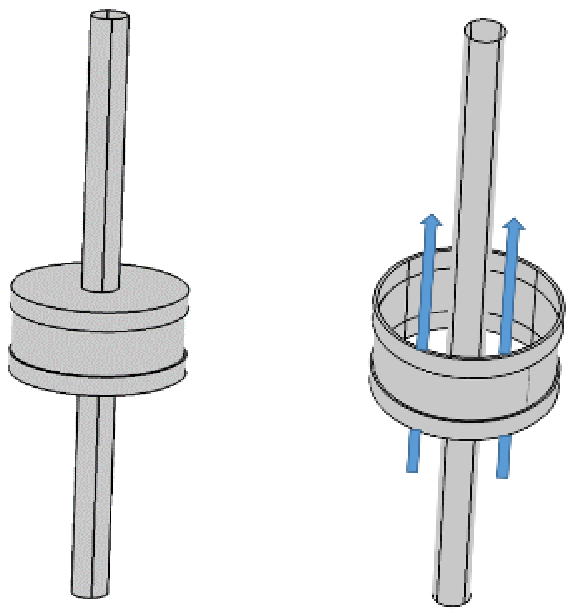
- Goal: Simulation of the electrolyte velocity distribution in the 400 MHz cavity.
- Physics module: Laminar flow combined with wall distance interface.
- Type of study: Stationary.
- Boundary conditions:
  - ➢ Inlet: Set with a laminar inflow of 50 lpm.
  - ➢ Outlet: Set with pressure.
  - ➢ Cavity walls: Non slip condition.
  - ➢ Gravity: Included with volume force node.

Fluid Dynamic simulations

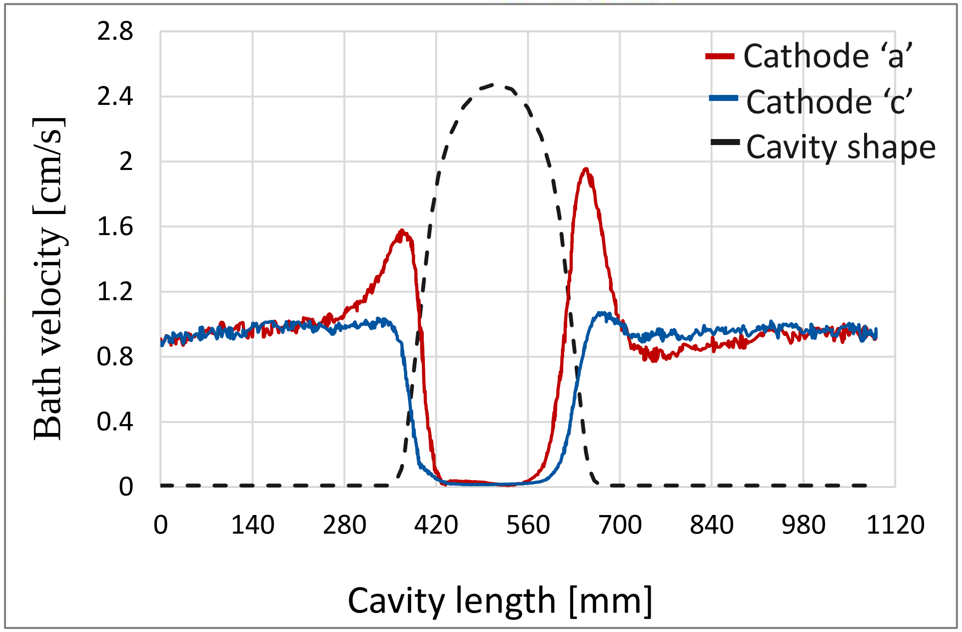
Results

Cathode geometries defined:

a. c.



Output from the FD simulations:



Electrolyte velocity distribution [m/s] with cathodes 'a' and 'c' respectively.

Electrolyte velocity distribution [cm/s] 20 mm far from cavity wall.

Fluid Dynamic simulations

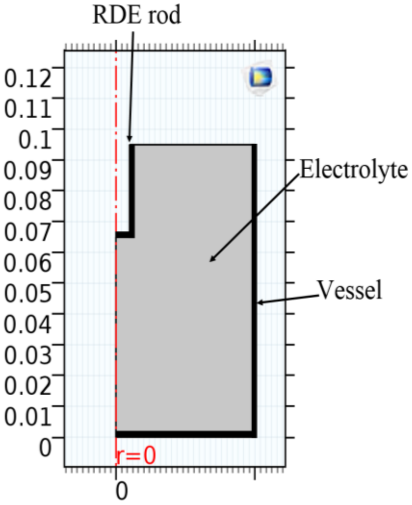
Objective

- Quantify the impact of fluid dynamics on the etching rate.

Model construction

Laboratorial RDE set-up

Model created in COMSOL



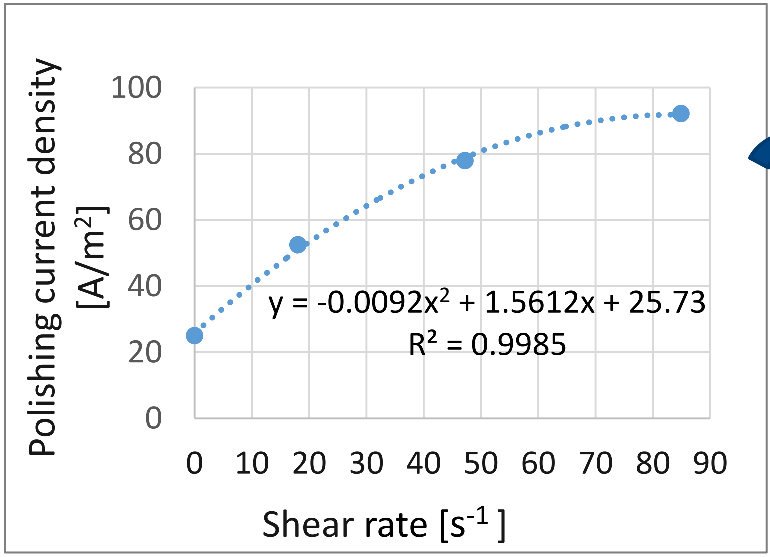
Output from the RDE model

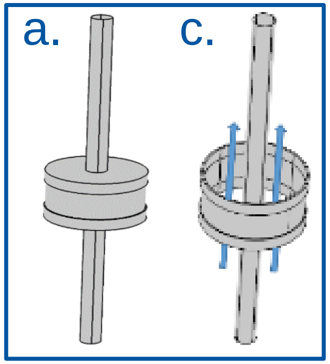
Speed of the RDE [rpm]	Polishing current density [A/m²]	**Shear rate [s^{-1}]**
0	25	**0**
100	52	**18**
200	78	**47**
300	92	**85**

Fluid Dynamic simulations

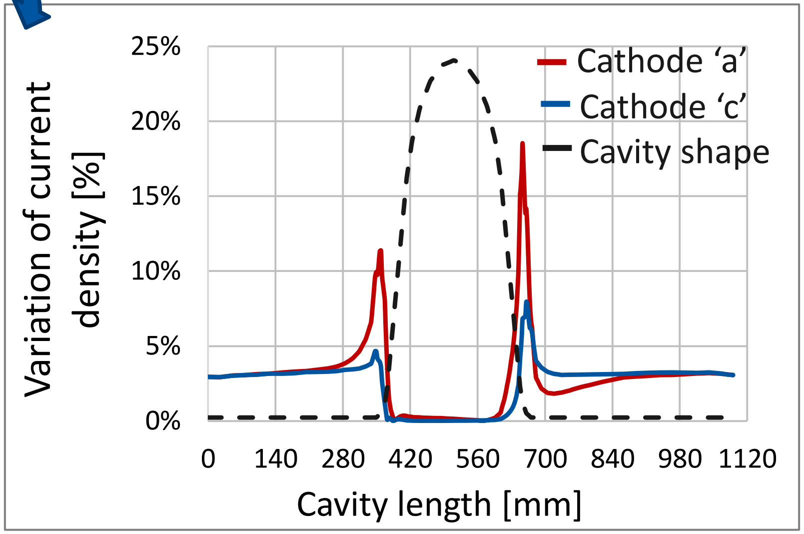
Results

Correlation identified:





Input for the FD simulations of the 400 MHz cavity with cathodes ‘a’ and ‘c’.



Summary

- Main results achieved:
  - Definition of an optimised cathode geometry.
    - Resulting in a minimum working potential, total current and power input;
    - Improved uniformity of the current density distribution.
  - Quantification of the impact of flow dynamics on the EP reaction rate evenness and its application to improve the cathode geometry.
- This work defined a modelling/simulating tool that can now promptly assess different SRF FCC cavity geometries.

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