The CERN Accelerator School

Introduction Afternoon Courses
Hands-on

19 June 2023

Hands-on courses

- **4** different **topics**, **4 groups** rotate through every 2 days
  - Group assignment shown this afternoon

- **RF measurements 1 (1st floor: Harvard 1 and 2)**
- **RF measurements 2 (2nd floor: Oxford 1 and 2)**
  - 12 experiments about 1 hour each, rotate through them

- **RF simulations**
  - CST Microwave Studio (on your own computer, we have a few laptops)
  - in this auditorium (in the back)

- **Longitudinal Tracking**
  - in this auditorium
  - in Python (on your own computers, we have a few laptops)

The CERN Accelerator School

Logistics – Hands-on groups

Hands-on Groups

Group 1	Group 2	Group 3	Group 4
Afshan Ashraf	Amelia Edwards	Mathieu Taquet	Michael Frey
Alessandro Cuttin	Anthony Gilfellon	Agnieszka Zwozniak	Arnaud Madur
Andriy Ushakov	Bastian Lorbeer	Alice Lucie Vanel	Chunlong Li
Birk Emil Karlsen-Baeck	Bernhard Schriefer	Artur Krawczyk	Ehtisham Khan
Burcu Yildirim	Bhagat-Taaj Sian	Conor Jenkins	Evgenij Plechov
Chen Kang	Diego Barrientos	Davide Lanaia	Fabian Metzger
Christian Herr	Domenic Nicosia	Denis Joassin	Gabriela Moreno
Dominic April	Eduardo Martínez López	Erik van der Kraaij	Jake Sawyer
Giulia Gnemmi	Jens Zappai	Hikmet Bursali	Jilei Sun
Guangyu Zhu	Laurence Wroe	Ioan-Charly T'Kint	Joan Revoltós i Barberà
Guodong Jiang	Leandro Intelisano	Jessica Golm	Lazar Nikitovic
HongMing XIE	Leon Kronshorst	Jorik Belmans	LIN GUO
Iker Rodriguez	Leonard Thiele	Krzysztof Guła	Marcel Hun
Ivan Karpov	Maciej Suminski	Marco Niccolini	Mariangela Marchi
Jia Li	Marc Ladiges	Mateusz Szczepaniak	Markus Wolf
Jorge Giner Navarro	Marco Diomede	Mattia Schaer	Michail Zampetakis
Lukas Braisz	Michela Neroni	Pablo Martinez-Reviriego	Niall Stapley
Nuaman Shafqat	MuYuan Wang	Pawel Borowiec	Nikolay Shurkhno
Ole Marqversen	Mykhailo Zhovner	Ping Wang	Pierrick HAMEL
Patrick Krkotic	Nils-Oliver Fröhlich	Quantang Zhao	Qi Chen
Peilin He	Pablo Echevarria Fernandez	Robert Abel	Reza Bazrafshan
Simon Karau	Quentin Vuillemin	Sebastian Goeller	Robin Svärd
Suzie Sheehy	Sam Pitman	Simone Chicarella	Shahnam Gorgi Zadeh
Tobias Loewner	Tiancai Jiang	Timo Fanselow	Shilong Li
Vitali Porshyn	WEI QIN	Yasuhiro Fuwa	Szymon Myalski
Wanisa Promdee	Xinghao Ding	Yosri Jlassi	Victoria Bjelland
Wenhao Huang	Zhengrong Wu		

no computer
no Windows
Tracking tutor
CST tutor

The CERN Accelerator School

Logistics – Hands-on groups

Days	20-21/6	23-24/6	26-27/6	28-29/6
Group 1	Longitudinal Tracking	CST - RF Simulation	RF Meas. Block B	RF Meas. Block A
Group 2	RF Meas. Block A	Longitudinal Tracking	CST - RF Simulation	RF Meas. Block B
Group 3	RF Meas. Block B	RF Meas. Block A	Longitudinal Tracking	CST - RF Simulation
Group 4	CST - RF Simulation	RF Meas. Block B	RF Meas. Block A	Longitudinal Tracking

RF Meas. Block A	1st floor Harvard
RF Meas. Block B	2nd floor Oxford

Hands-on RF Measurements – Teaser

- **Spin-off from the CAS Advanced Course afternoon hands-on sessions**
  - **But…**

Hands-on RF Measurements – Some Details

- **Much more students (>100), and fortunately also more instructors (10)**
  - **Students: (large) spread in background knowledge and experience on RF measurements**
    - Teams of 4..5 students with a good spread
  - **Instructors: Professionals and (semi)-amateurs**
    - In RF you always are a student!

- **More experimental setups**
  - **12 experimental tables with VNAs, SAs, oscilloscopes, RF generators and more**
    - Unfortunately located on different floors
  - **All students will execute each experiment**
    - Still, some changes, alterations on individual experiments may occur over the 2-weeks
  - **Additional after-hours experiments**
    - "Happy hour with Piotr" on request

Hands-on RF Measurements – Block A, 1st floor (Harvard)

1. **Cylindrical cavity characterization (single cell, "pillbox" like) – 1 hour**
   Instructors: Yegor, Manfred
   – Understanding eigen-modes and fields
   – Characterizing the accelerating mode in terms of Q_L, Q_0, f_{res}, under / over / critical coupling, Smith chart, etc.
2. **Bead-pull measurement: R/Q characterization of a cavity – 1 hour**
   Instructors: Christine, Yegor
   – Slater theorem, S11 frequency- and S21 phase shift methods
3. **Cavity operations in a feed-back loop and in time-domain – 1½ hour**
   Instructors: Ben (1st week), Heiko (2nd week)
   – Understanding low-level RF controls and beam excited signals on a cavity
4. **Beam-coupling impedance measurement – ½…1 hour**
   Instructor: Manfred
   – On a stretched-wire coaxial test setup
5. **High-frequency measurements of waveguide components – 1 hour**
   Instructors: Alexey, Manfred
   – WG calibration, characterization of 2-port WG components, e.g., BP filter, isolator, etc.
6. **RF-characterization of material properties – 1 hour**
   Instructors: Christine, Piotr
   – With a "golden" cavity, or waveguide or strip-line setup
   – Also, fun with tobacco box resonators!

Hands-on RF Measurements – Block B, 2nd floor (Oxford)

1. **Traveling-wave structure – 1 hour**

   Instructors: Andrea, Nuria

   – VNA characterization of a traveling-wave accelerating structure

2. **VNA measurement techniques in frequency and time-domain – 1 hour**

   Instructors: Nuria, Alexey

   – Calibration, (differential) time-domain, (advanced) TDR (Γ and Z), virtual ports, port extension, gating, transformations.

3. **Passive n-port characterization, impedance matching exercise – 1 hour**

   Instructors: Nuria, Andrea

   – Filters, (LPF, BPF, HPF), couplers ($180°$, $90°$, x dB directional, rate-race, etc.), circulator, equalizer, etc.

   – $\lambda/4$ lossless TL as impedance transformer, impedance matching with a 3-stub tuner

4. **Measurements on non-linear and active RF components – 1 hour**

   Instructor: Michele, Piotr

   – Amplifiers (NF, gain, IP3, power sweep, etc.), mixers

5. **Characterization of beam pickups, radar – 1 hour**

   Instructors: Piotr, Alexey

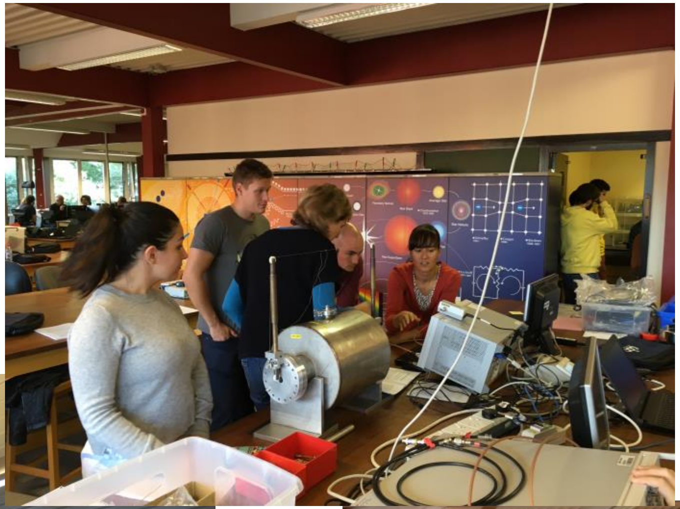
   – Characterization of EM beam pickup (split-plane, button, strip-line, cavity) in FD and TD, fun with radar!

6. **Basics on AM and FM – 1 hour**

   Instructors: Michele, Piotr

   – AM, FM, narrowband FM, in time and frequency-domain

Learning by Doing



Special Topic RF Course – Numerical Analysis of RF Problems

N. Baboi, H. Glock, A. Neumann, R. Singh, S. Udongwo, C. Vollinger, M. Wendt

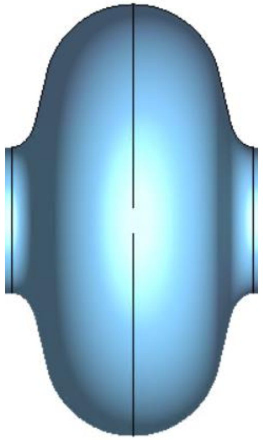
Supervisors: Dr. Shahnam Gorgi Zadeh, Dr. Rama Calaga, Prof. Ursula van Rienen

Content

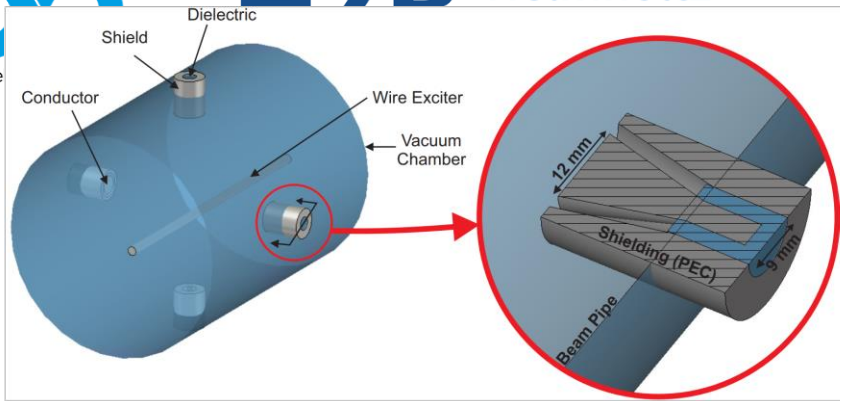
- Parametric modelling
- Eigenmode simulation
- Time domain and Wakefield simulation
- Particle in Cell (PIC) simulation

Parametric Modelling

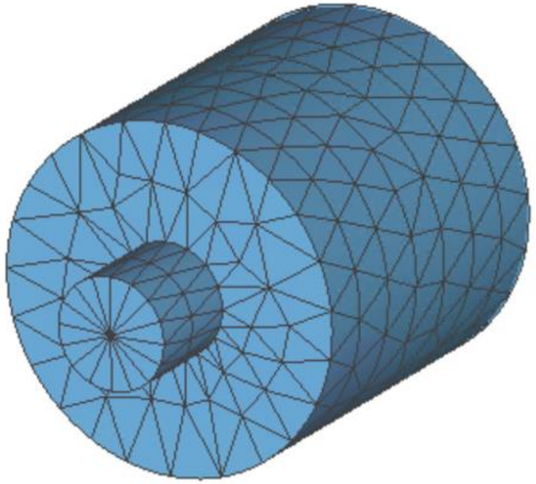
- Parametric modelling is a feature in CAD software that allows designers to create and modify 2D or 3D models flexibly and efficiently.



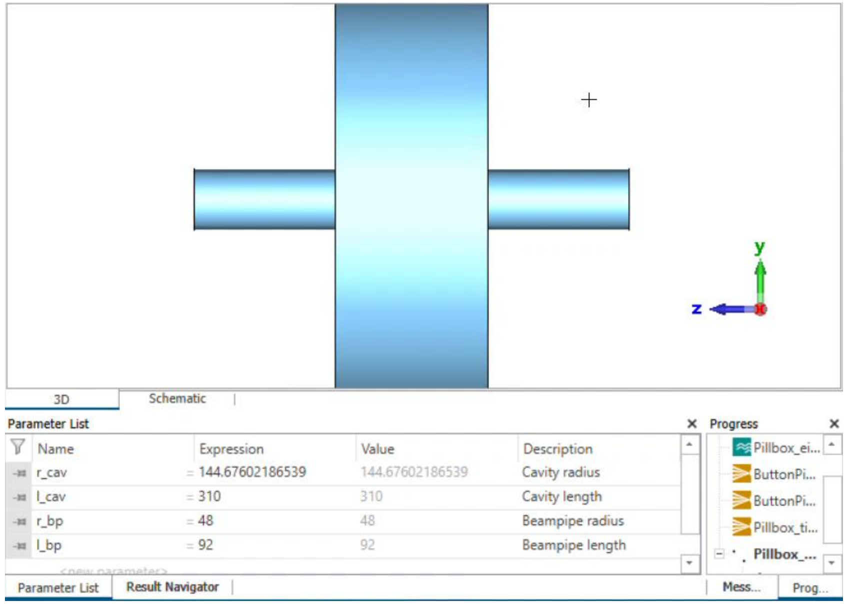
TESLA Cavity mid-cell



Button Beam Position Monitor (BPM)



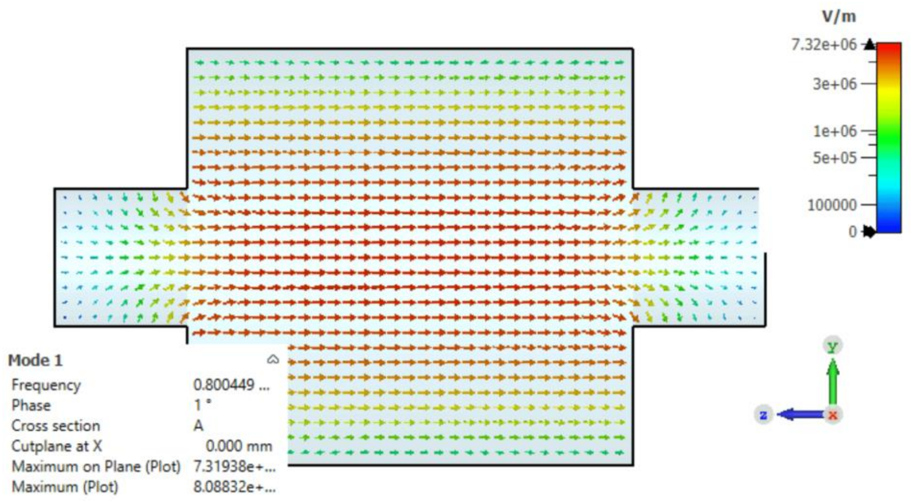
Pillbox Cavity



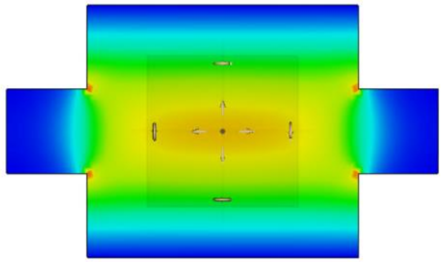
Parametric Modelling

Eigenmode Simulation

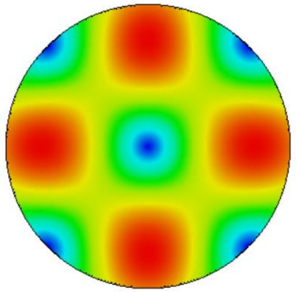
- Eigenmode analysis is a method for analysing the resonant modes of an electromagnetic system.



TM010 mode electric field simulation



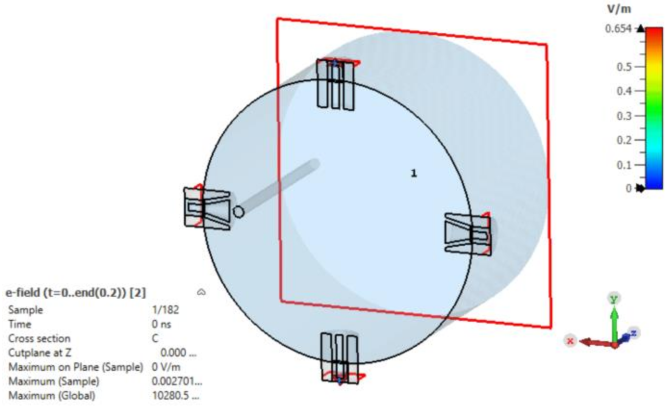
TM010 mode electric field contour



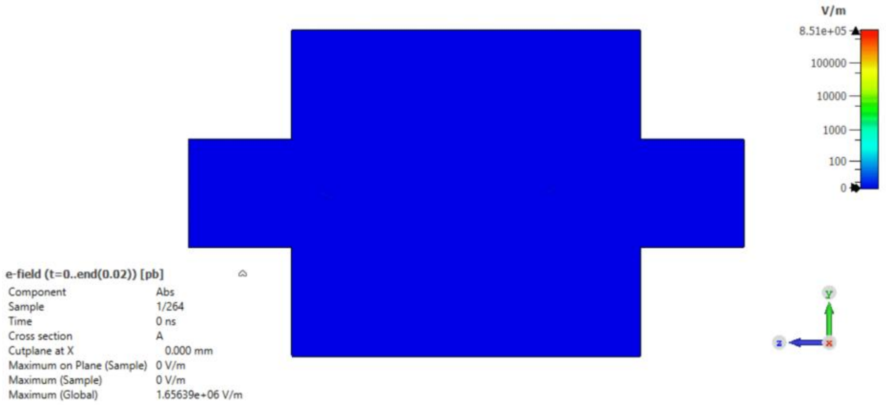
HOM electric field contour

Time Domain and Wakefield Simulations

- Wakefield solver is essentially an extension of a time-domain solver to simulate the interaction of charged particle beams with the environment.



Time domain simulation of a button BPM excited by a wire

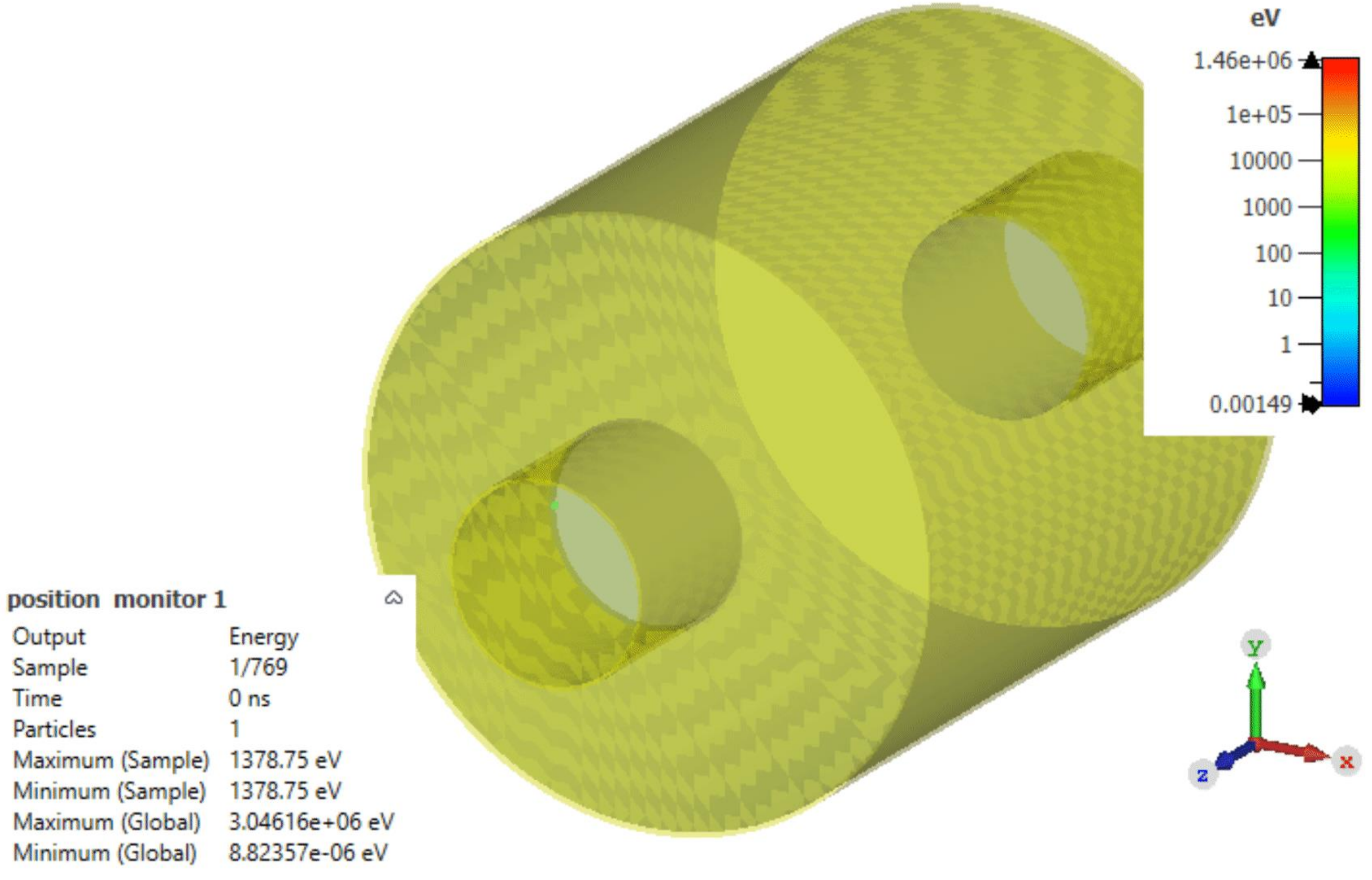


Wakefield Simulation of a pillbox cavity

Particle in Cell (PIC) Simulation

- PIC simulation is a tool for simulating the behaviour of charged particle beams in complex electromagnetic environments

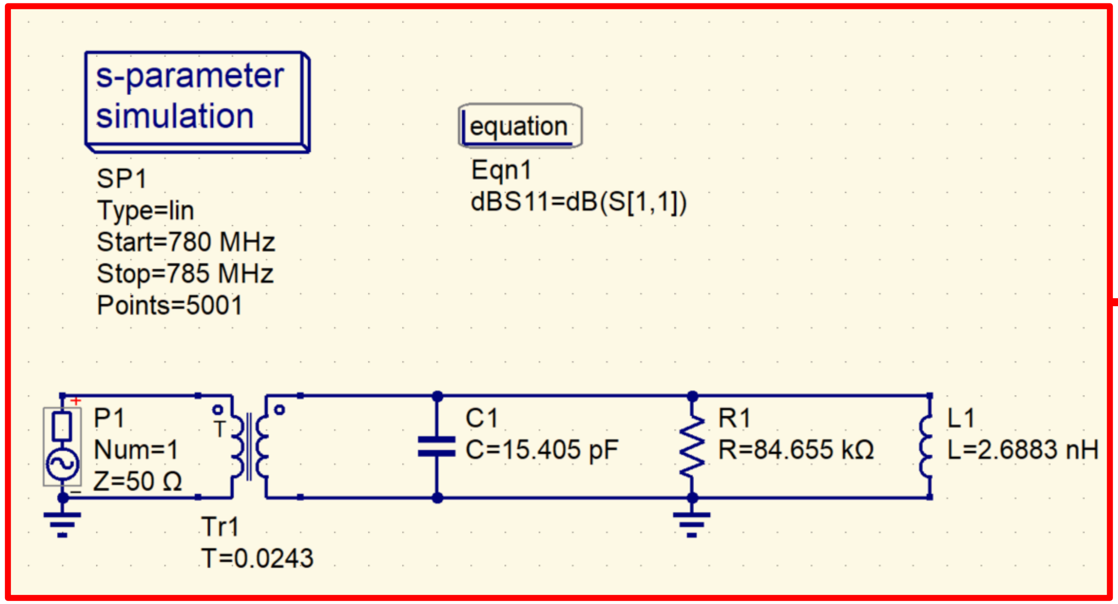
- In the tutorial, multipacting is simulated in a pillbox cavity.



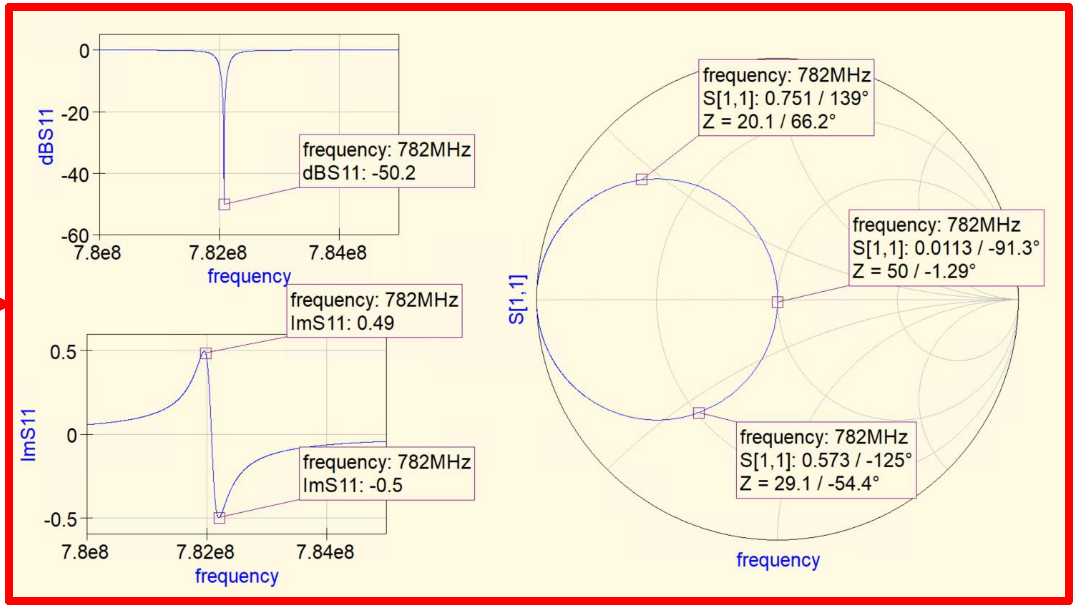
Multipacting in pillbox cavity

Equivalent Circuit Analysis - Qucs Studio

- Equivalent circuit simulations provide a simplified representation of complex systems, enabling efficient analysis and prediction of system behaviour.



RLC equivalent circuit of a resonant mode.



Transmission curves and Smith‘s chart of the equivalent circuit