# RF design of the CLIC-K module and BOC and CC measurements

Ping Wang, Alexej Grudiev

19.03.2024

Acknowledgements:, Karol Scibor, Alan Saillet, Emmanuel Berthome, Fritz Motschmann, Laurene Giordanino, Pedro Morales Scanchez, Nuria Catalan Lasheras, Benoit Riffaud, Igor Syratchev, Xiaowei Wu, Steffen Doebert, Matthew John Capstick, Carlo Rossi

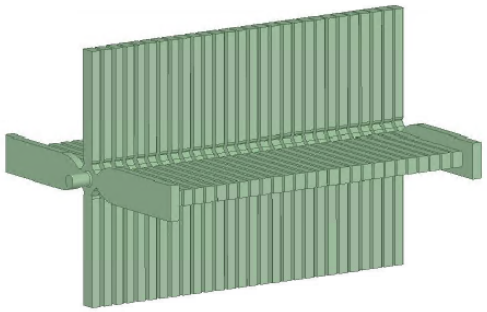
# Outline

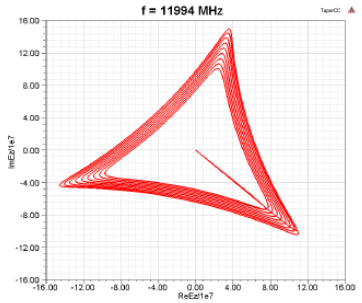
- **Background**
- RF design of the CLIC-K module
- RF measurement of the BOC pulse compressor
- RF measurement of the bowl cavity
- Summary

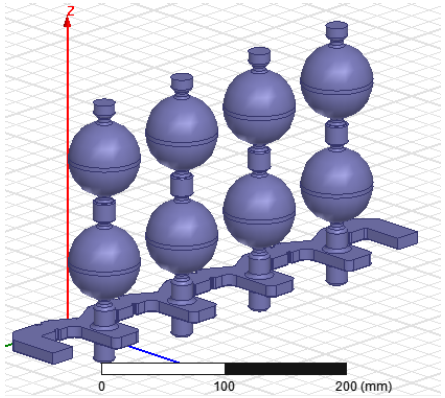
# Introduction of Klystron-based CLIC

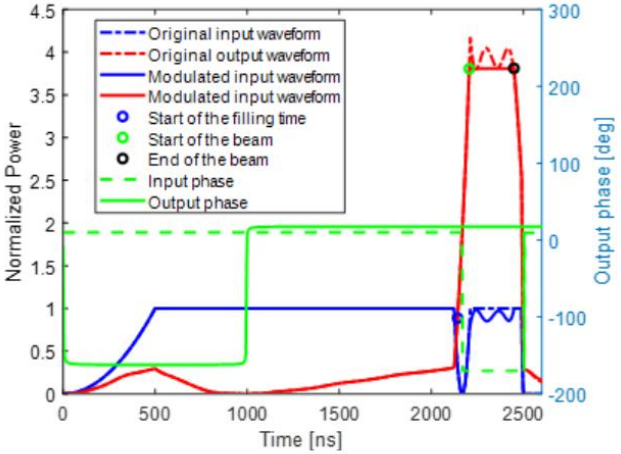
- Klystron-based CLIC was proposed due to possible low cost for 380 GeV

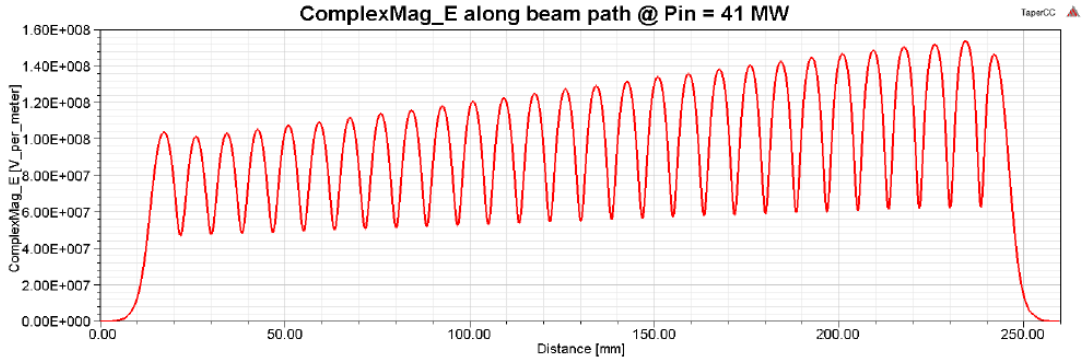
- CLIC-K structure
- Pulse compressor with correction cavity chain

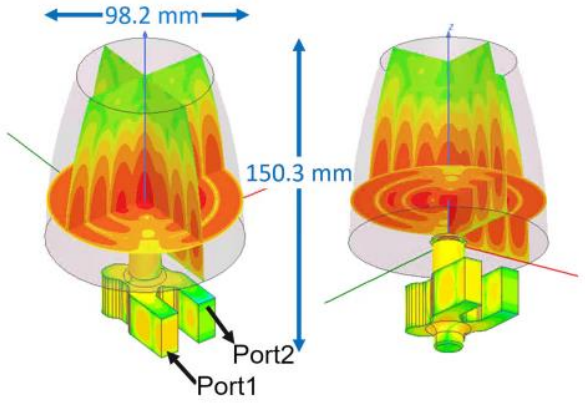


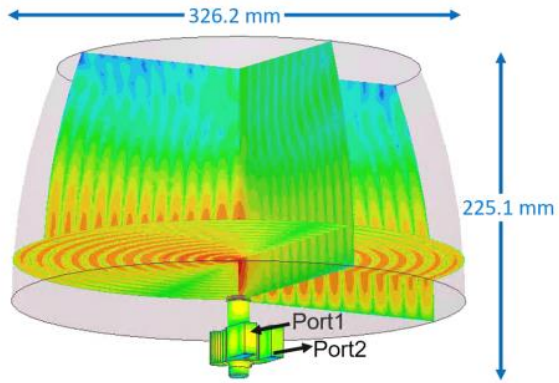


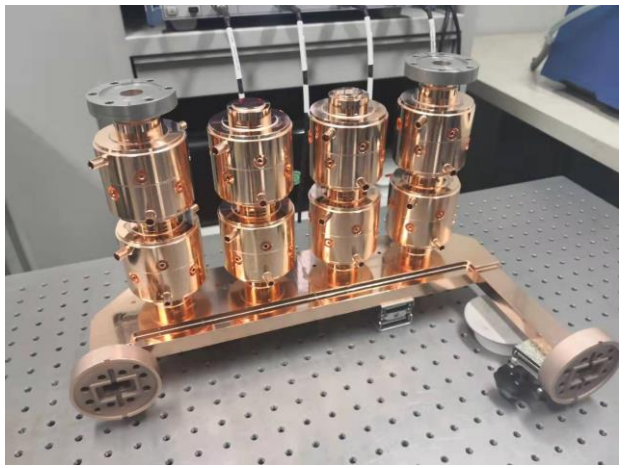



# Challenges of Klystron-based CLIC

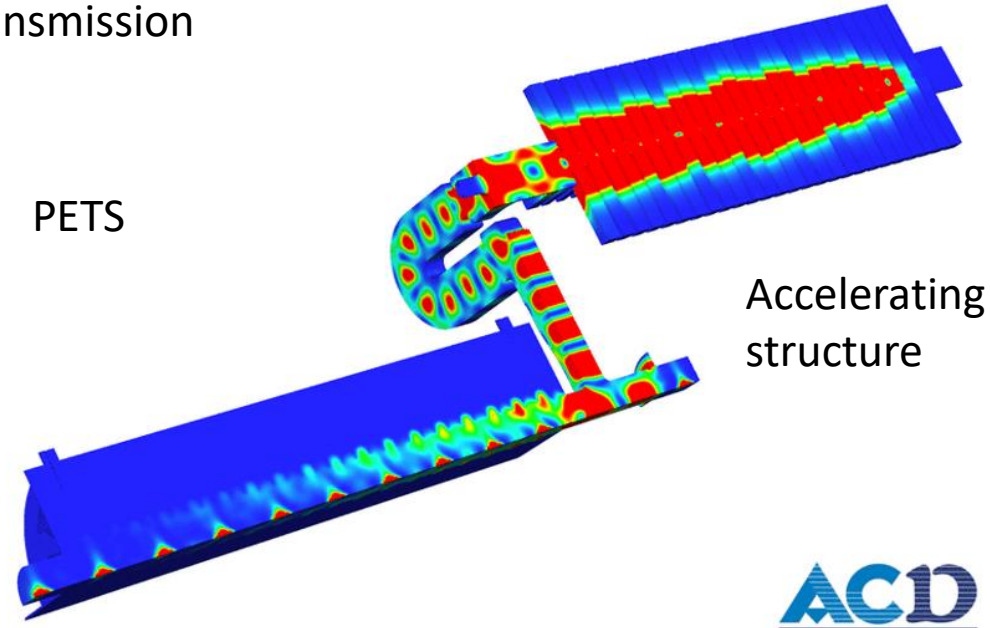
- RF loss of the RF network
- Power gain of the pulse compression system

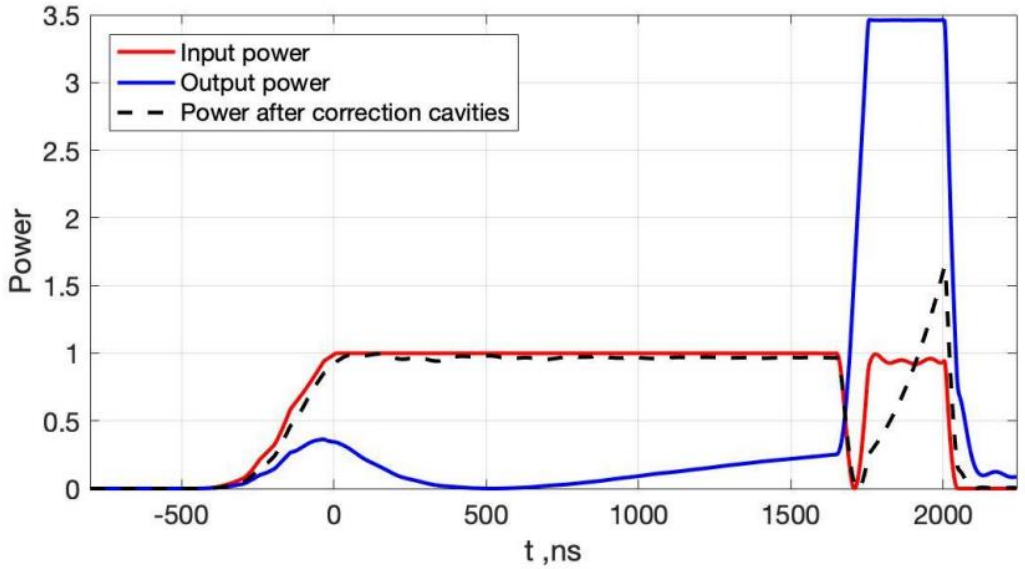


Short path for RF power transmission

PETS

Accelerating structure

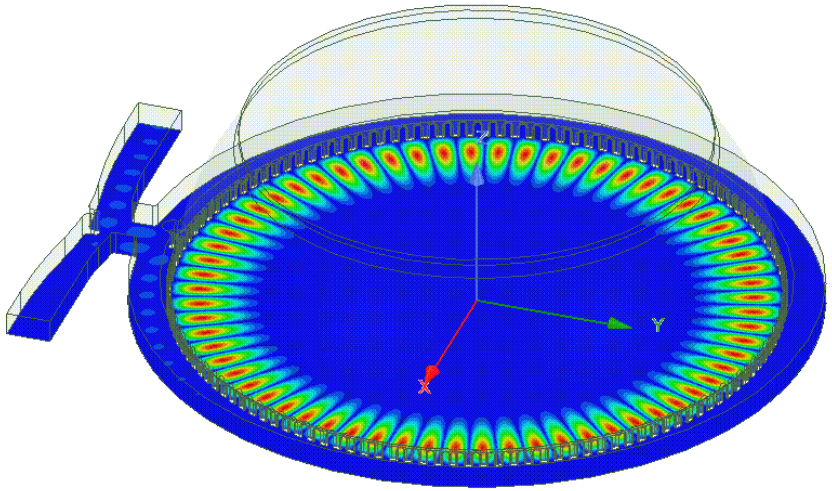


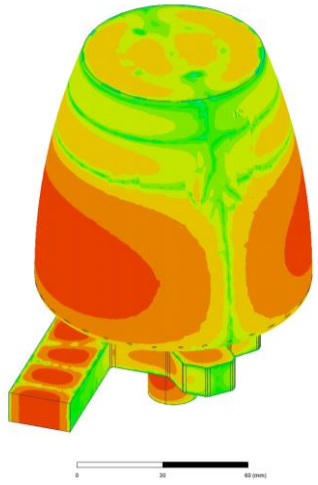


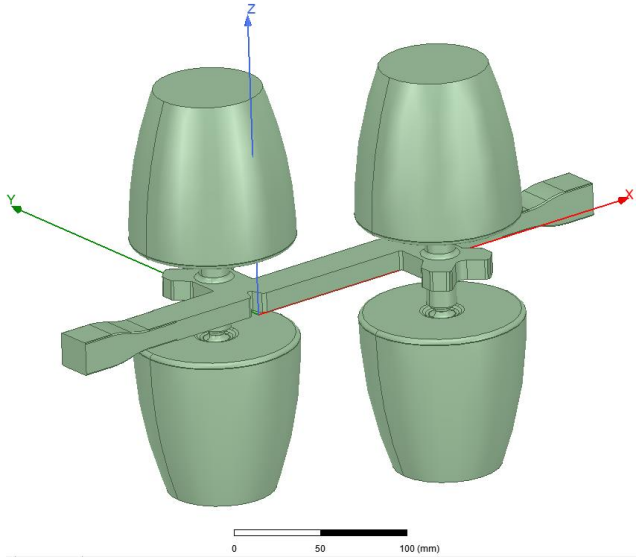
# Challenges of Klystron-based CLIC

- RF loss of the RF network → Double-height waveguides
- Power gain of the pulse compression system → Larger unloaded quality factor

| | Power gain | Qs | Qc | Beta_s | Beta_c | Ns | Nc |
|---|---|---|---|---|---|---|---|
| **New system** | **3.8** | **2.35e5** | **7.5e4** | **6.6** | **1.95** | **1** | **4** |
| First Prototype | 3.5 | 1.79e9 | 4.5e4 | 5.98 | 1.45 | 2 | 8 |





# Outline

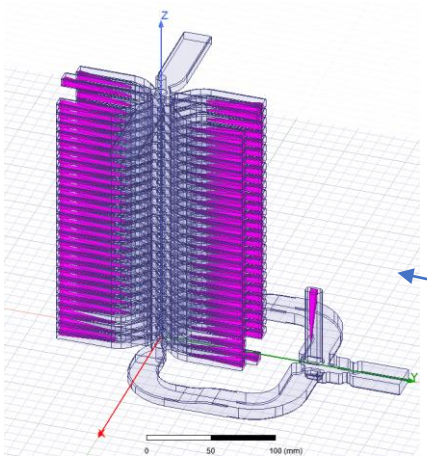
- Background
- **RF design of the CLIC-K module**
- RF measurement of the BOC pulse compressor
- RF measurement of the bowl cavity
- Summary

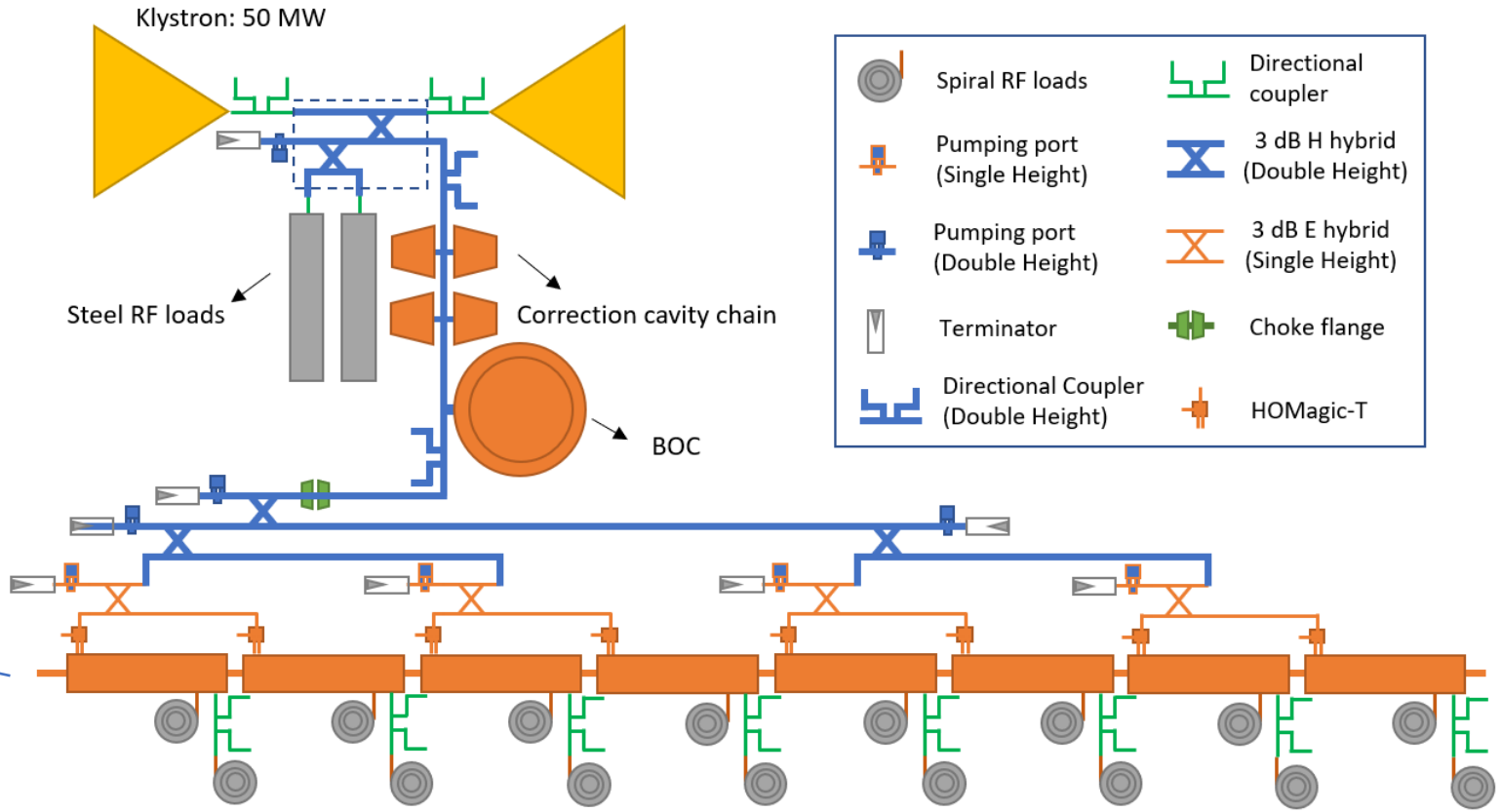
# Preliminary layout of RF module for klystron-based CLIC

- Input power for Linacs: 40.6 MW

- Two klystrons
- Power of klyston: 50 MW

- Power gain: 3.80
- RF loss in RF system: 13%

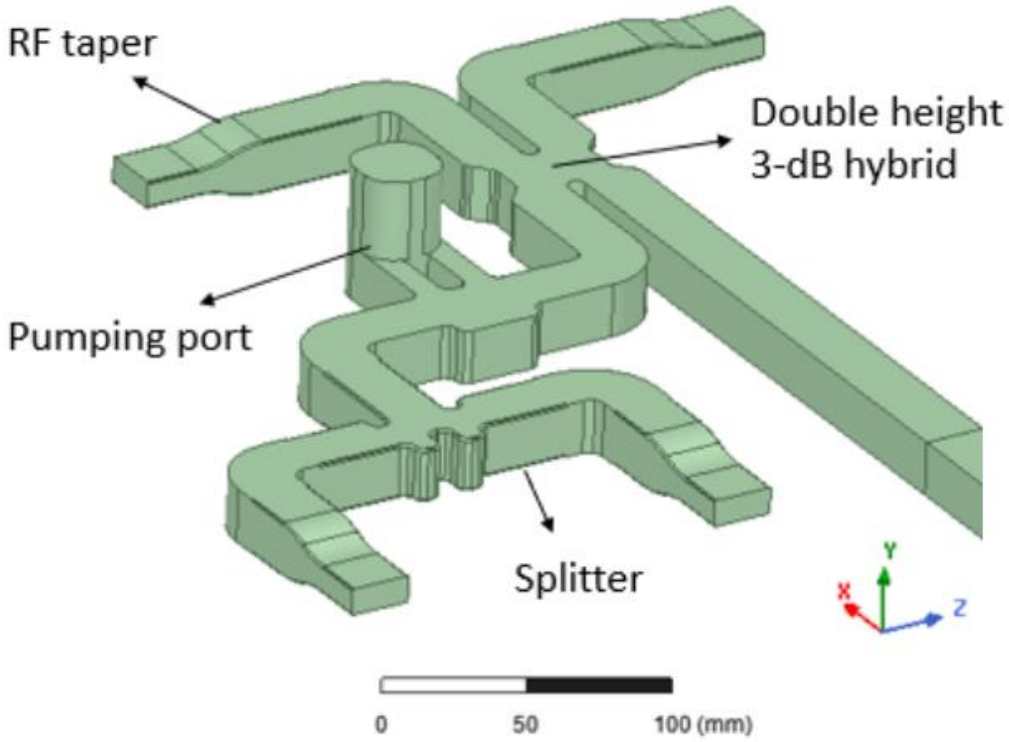


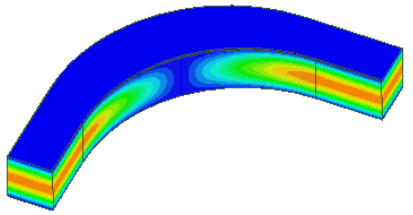



**[1]** Ping Wang, M. Capstick, N. Catalan Lasheras, et al., RF design of the waveguide network for the klystron-based clic module. Proc. 14th Int. Particle Accel. Conf. (IPAC), Venezia, Italy, 2023.

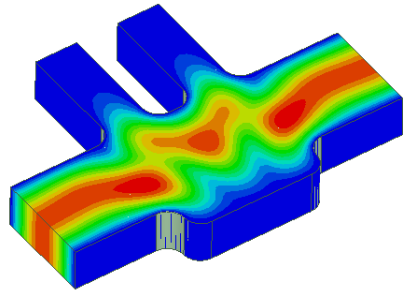
# RF combiner

- Two combine the RF power from two klystrons
- The ability to absorb the RF power  from two klystrons

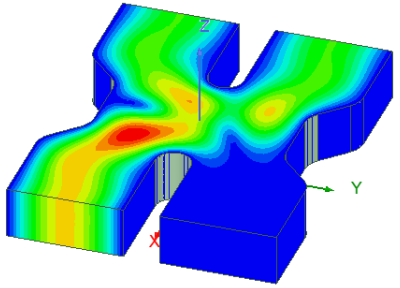


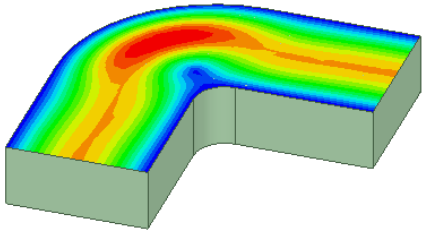
Double Height E-bend



Single Height Pumping port



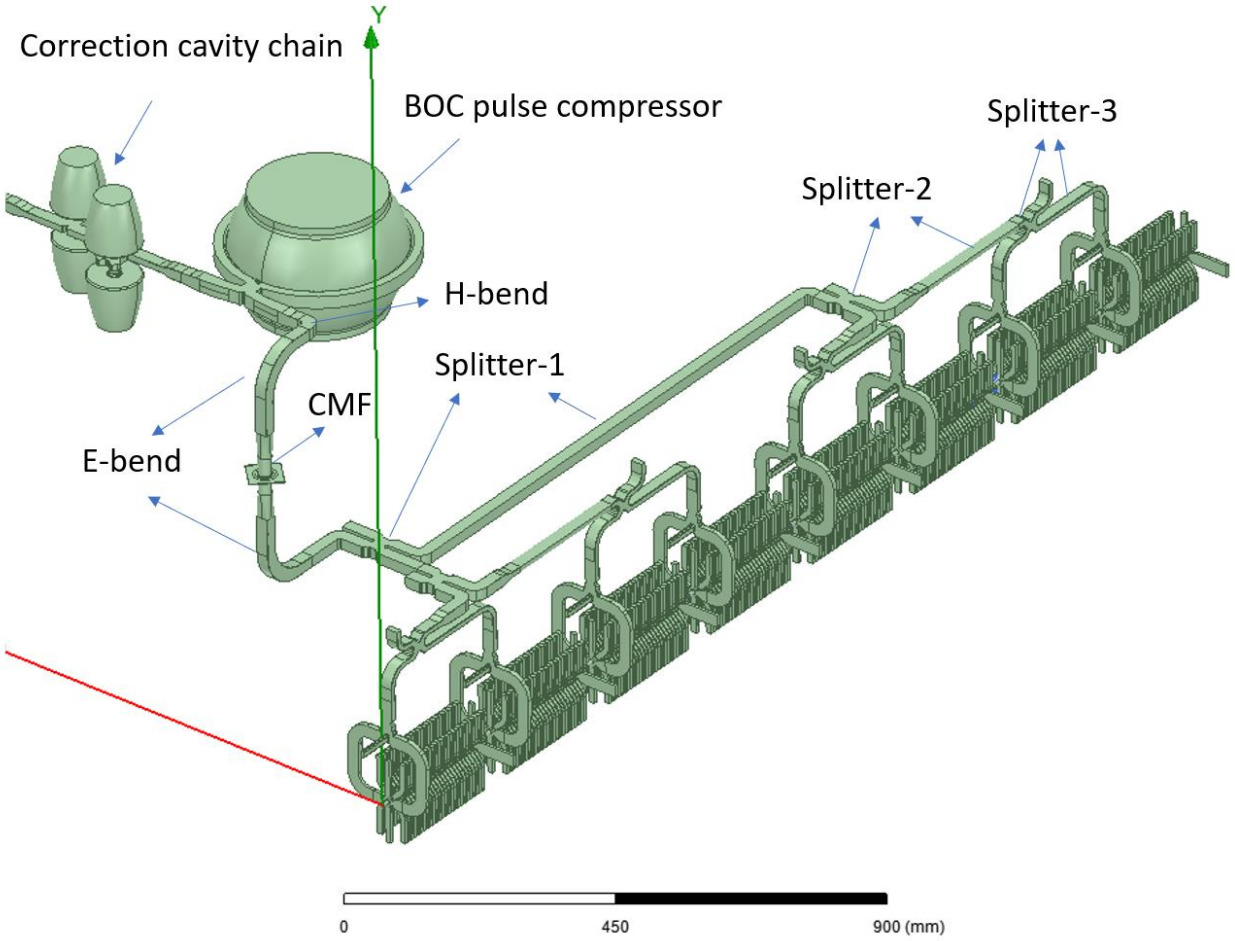

Single Height 3-dB hybrid



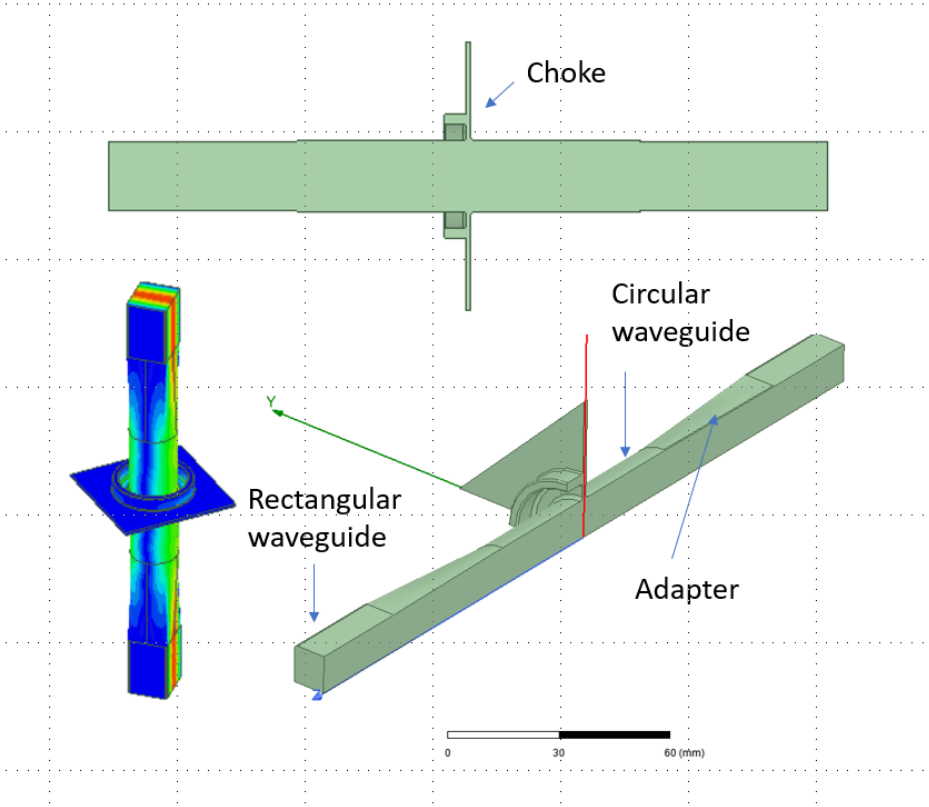
Single Height H-bend

# RF splitter

- Choke Mode Flange based scenario

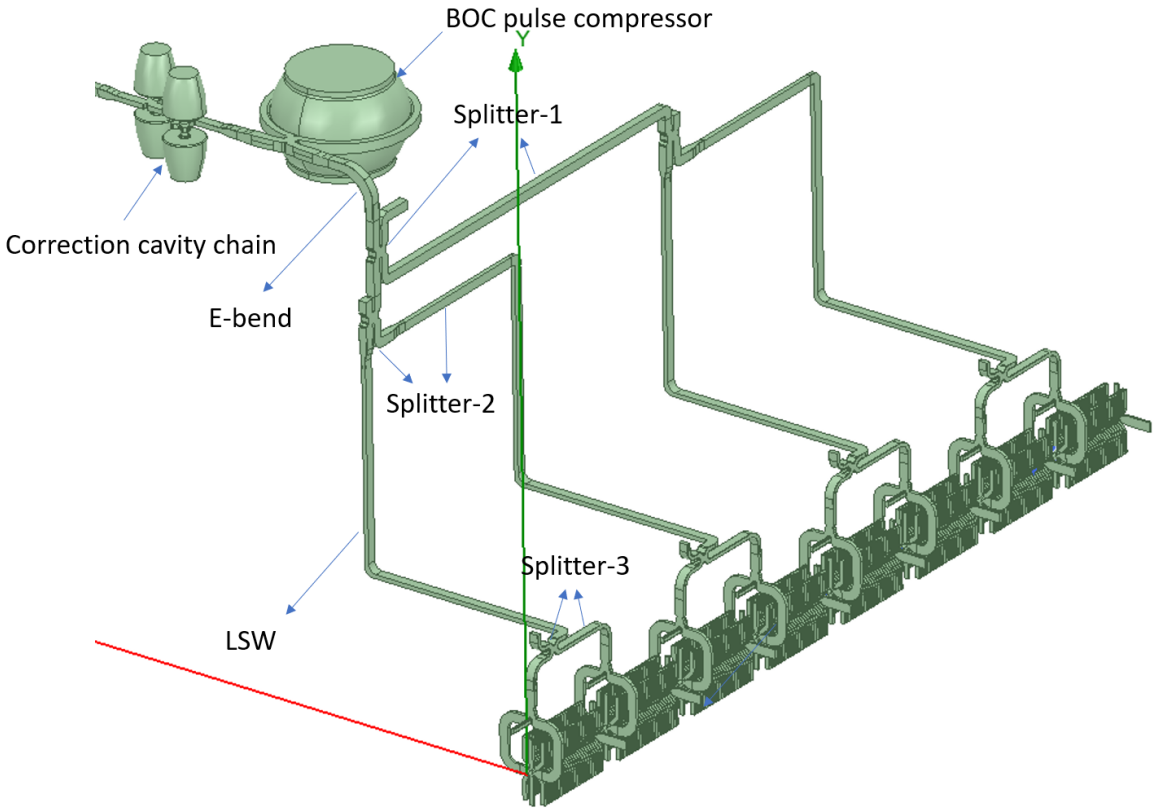



| X direction | Y direction | Z direction |
|---|---|---|
| ± 0.89 mm | ± 0.12 mm | ± 0.96 mm |



# RF splitter

- L Shape Waveguide based scenario



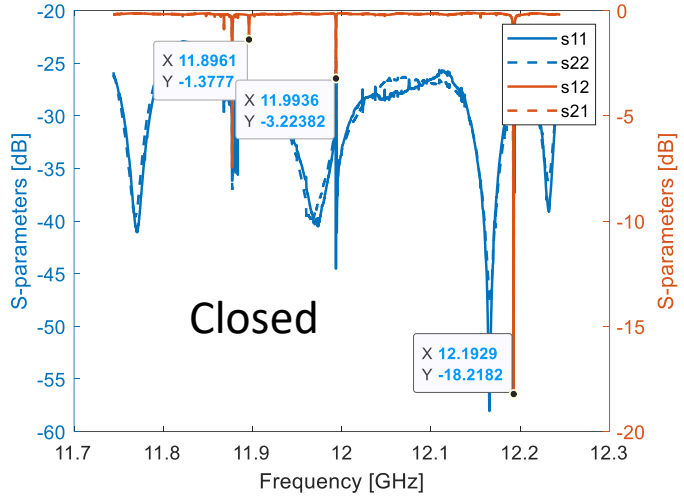

- RF loss calculation of the two scenarios

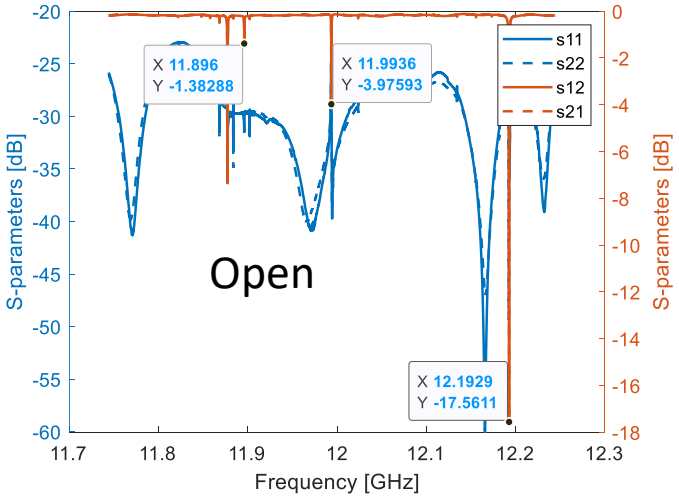
| Components | RF loss (CMF) | RF loss (LSW) |
|---|---|---|
| Combiner | 0.66% | 0.66% |
| DHWG-90 | 4.01% | 4.01% |
| CCC | 1.29% | 1.29% |
| BOC | 2.01% | 2.01% |
| H-bend | 0.074% | 0.0% |
| E-bend | 0.28% | 0.28% |
| CMF | 0.29% | 0.0% |
| E-bend | 0.28% | 0.0% |
| Splitter-1 | 0.98% | 0.98% |
| Splitter-2 | 0.65% | 0.85% |
| Splitter-3 | 0.62% | 0.82% |
| LSW | 0.0% | 2.22% |
| Overall | 10.66% | 12.25% |

# Outline

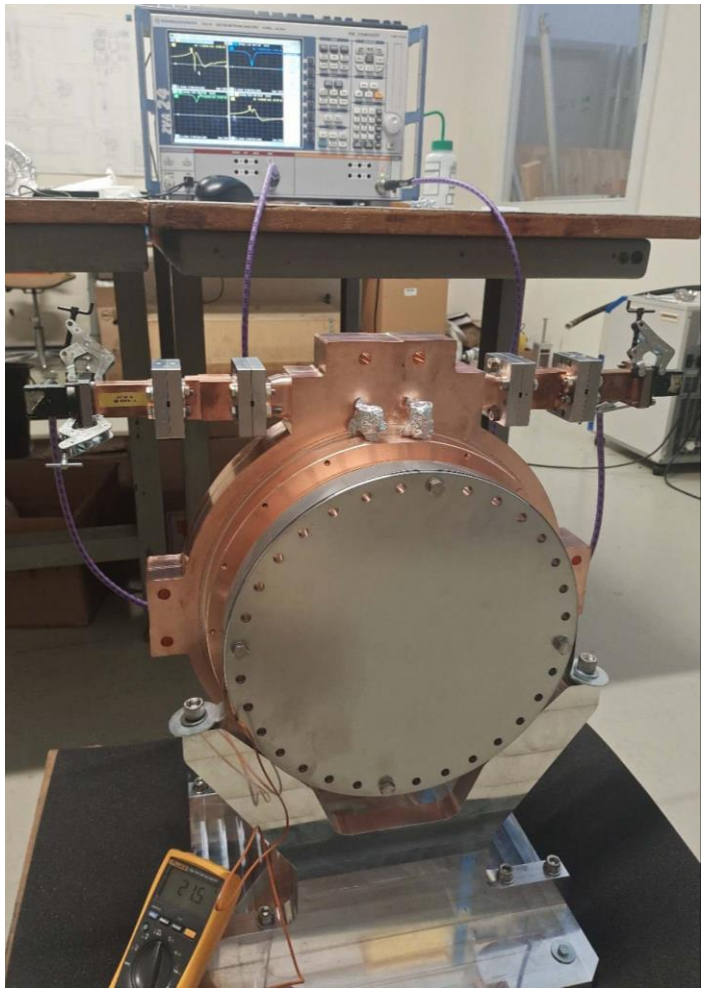
- Background
- RF design of the CLIC-K module
- **RF measurement of the BOC pulse compressor**
- RF measurement of the bowl cavity
- Summary

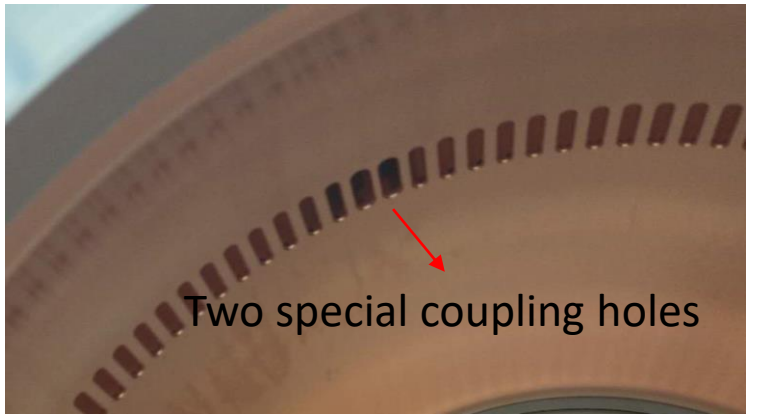
# RF measurement of the BOC pulse compressor

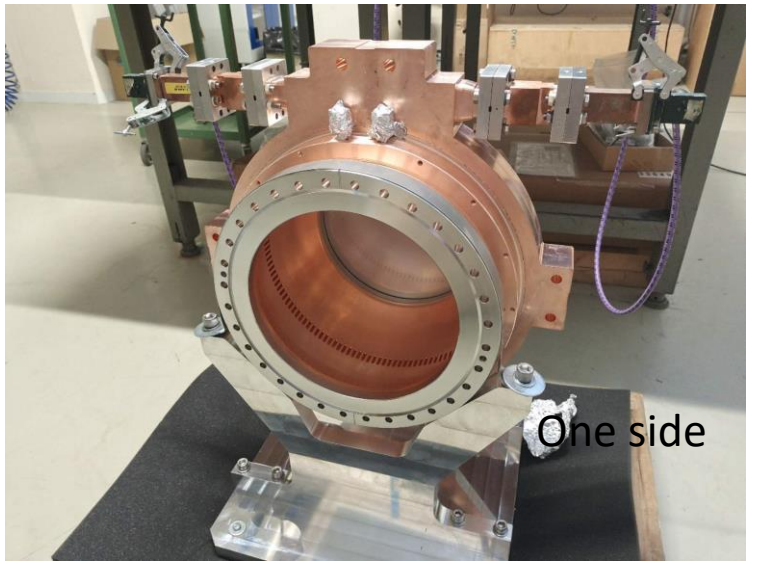



S-parameters of the BOC



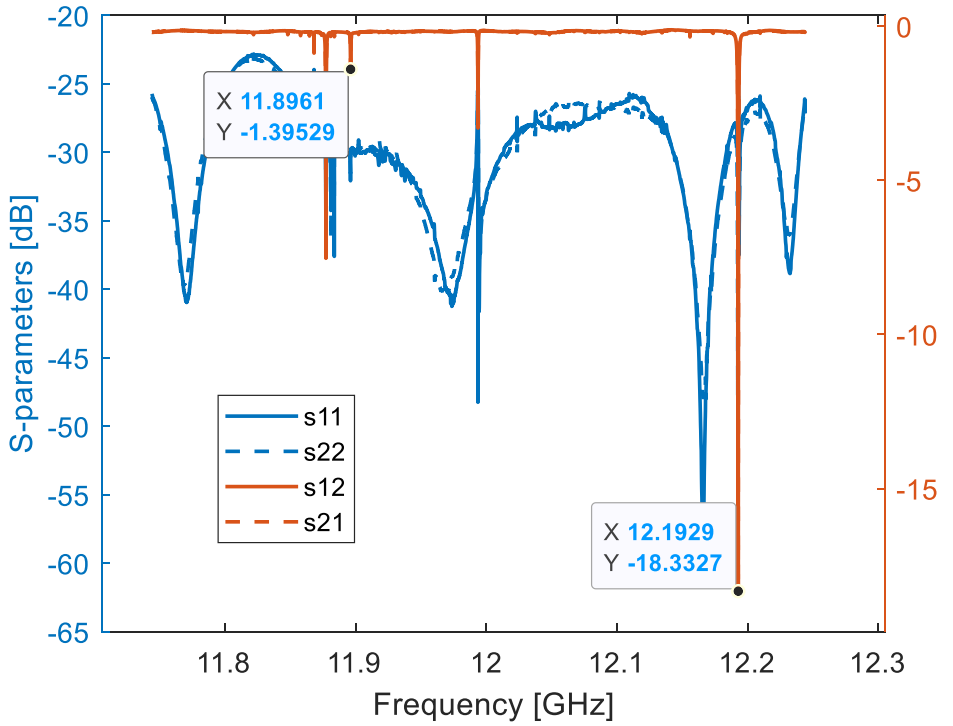


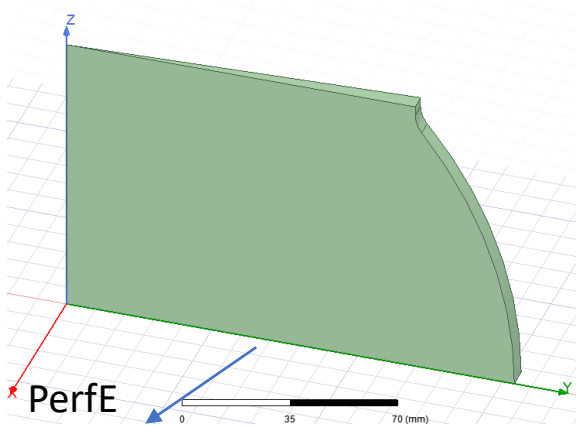



# RF measurement of the BOC pulse compressor

Measurement @ 500 MHz span and 21.5 °C

Two nearby modes: 11.896 GHz and 12.193 GHz

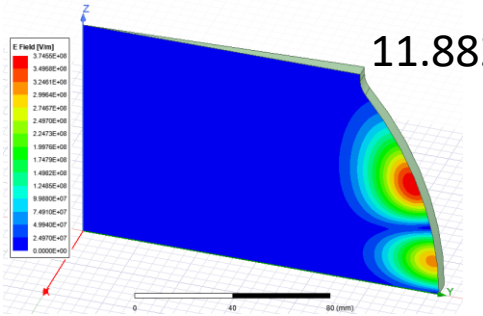


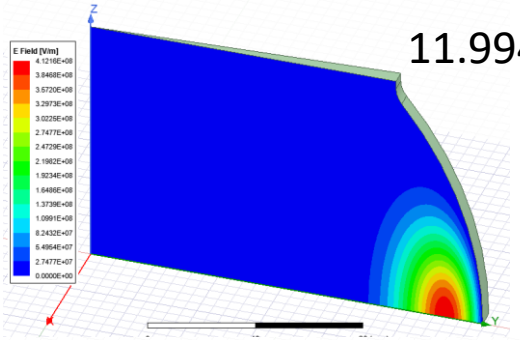
- PerfE
- PerfH

| Eigenmode | Frequency (GHz) | Q |
|---|---|---|
| Mode 1 | 11.8823 +j 0.000167297 | 35512.4 |
| Mode 2 | 11.9940 +j 2.34818e-05 | 255389. |
| Mode 3 | 12.5355 +j 0.000178454 | 35122.4 |

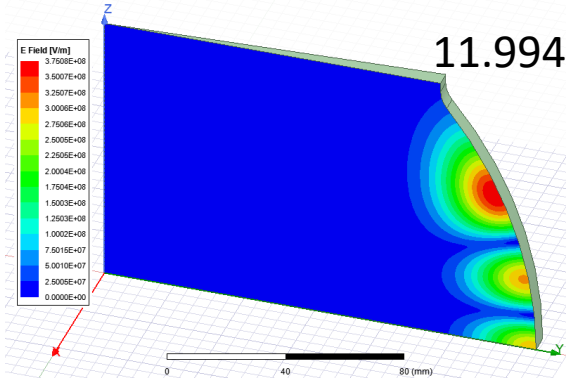
| Eigenmode | Frequency (GHz) | Q |
|---|---|---|
| Mode 1 | 11.5545 +j 0.000161900 | 35684.1 |
| Mode 2 | 12.2095 +j 0.000172763 | 35335.9 |
| Mode 3 | 12.3334 +j 2.38419e-05 | 258650. |



11.882 GHz



11.994 GHz

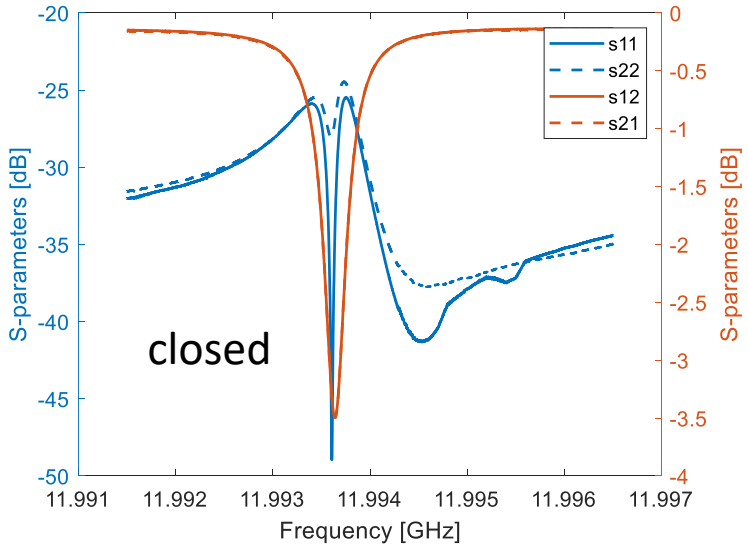


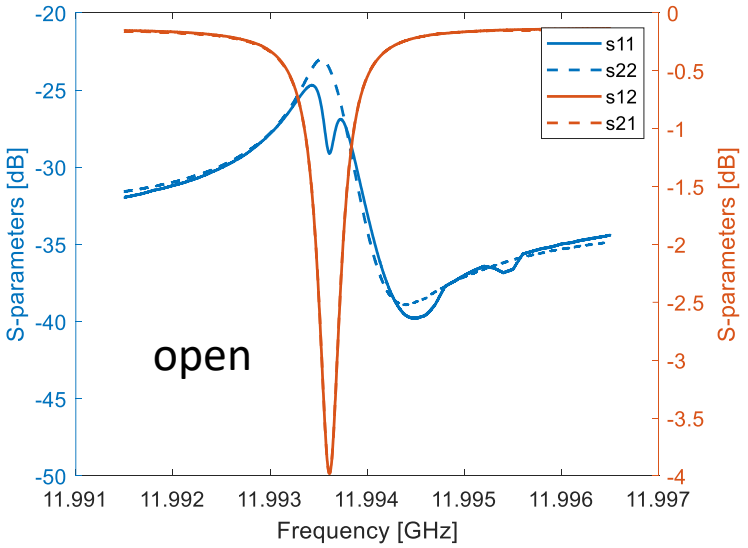
11.994 GHz

# RF parameters of the BOC pulse compressor

| | Frequency [GHz] closed | Frequency [GHz] open |
|---|---|---|
| Air & 21.5℃ | 11.9936 | 11.9936 |
| Vacuum & 21.5℃ | 11.9968 | 11.9968 |
| Vacuum & 34.9℃ | 11.994 | 11.994 |

| | Measured open | Measured closed | Designed |
|---|---|---|---|
| Q0 | 1.91e5 | 2.15e5 | 2.36e5 |
| Qe | 4.30e4 | 4.28e4 | 3.58e4 |
| Beta | 4.44 | 5.03 | 6.6 |

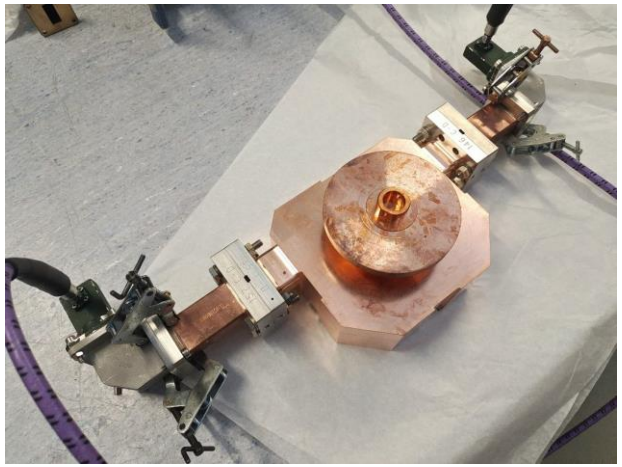


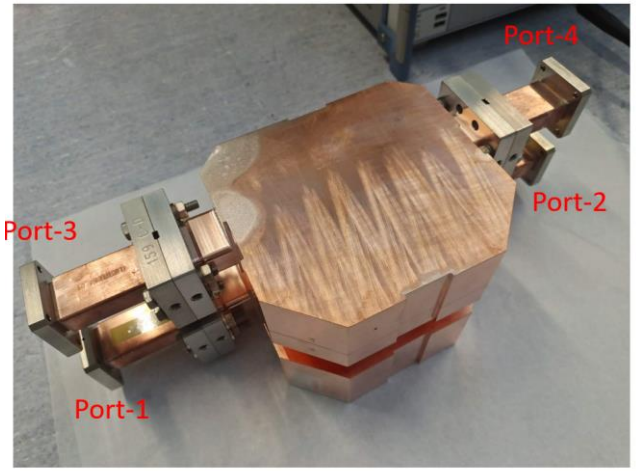



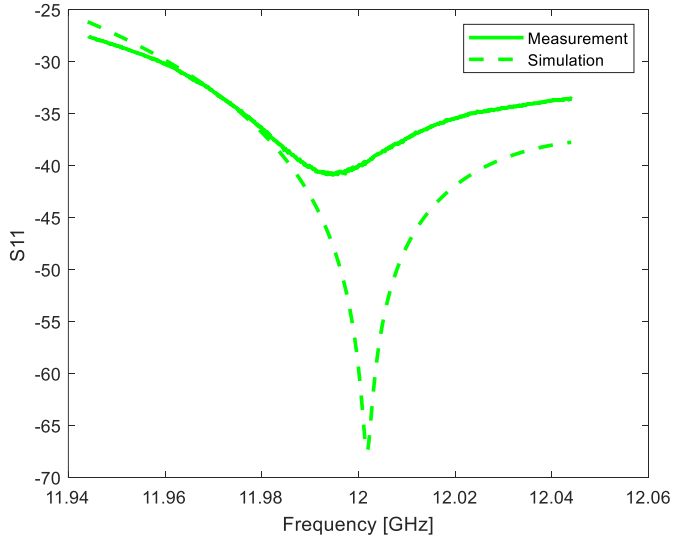
# Outline

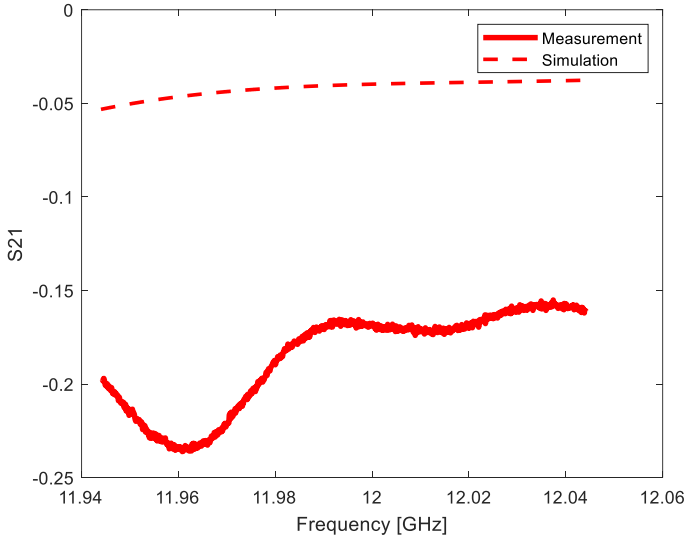
- Background
- RF design of the CLIC-K module
- RF measurement of the BOC pulse compressor
- **RF measurement of the bowl cavity**
- Summary

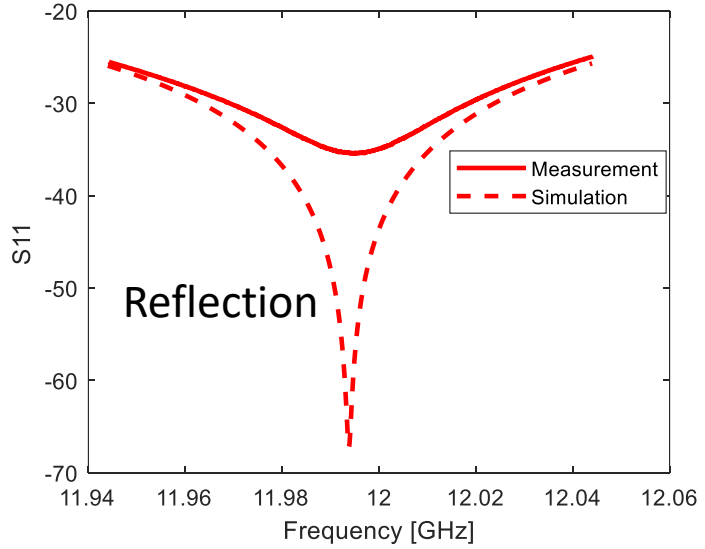
# RF measurement of the RF rotator

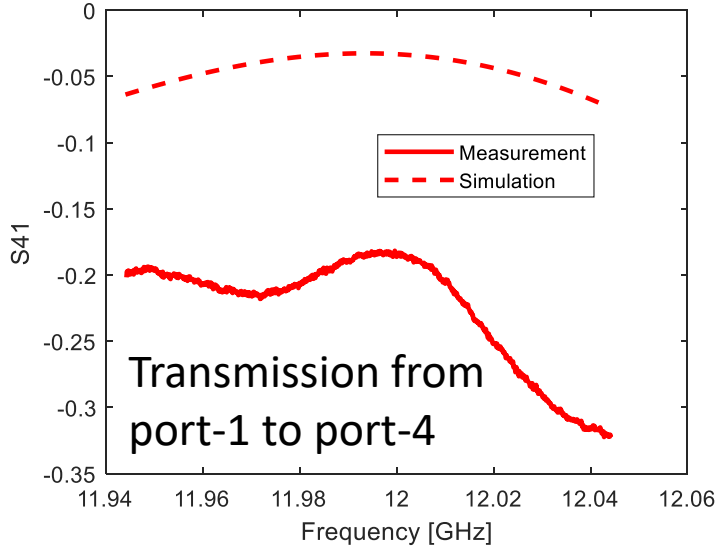




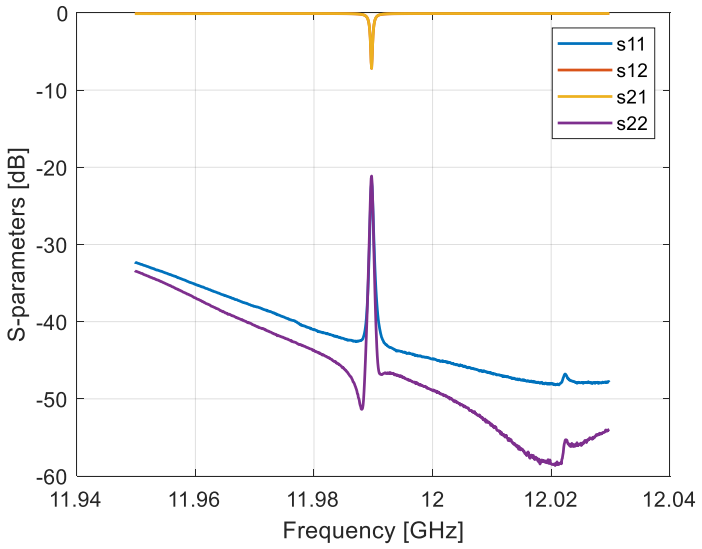



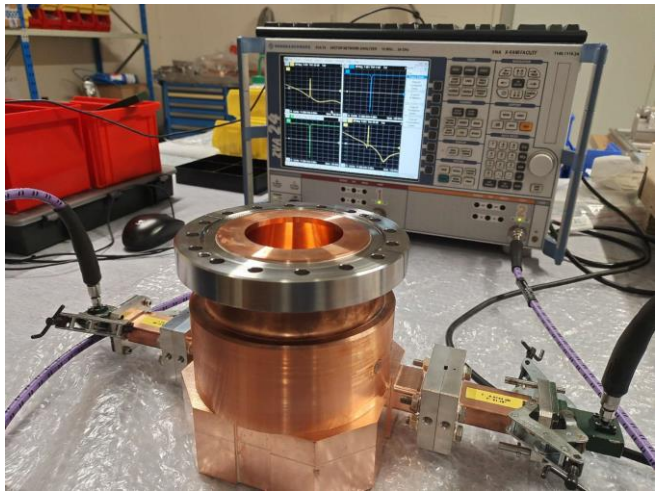



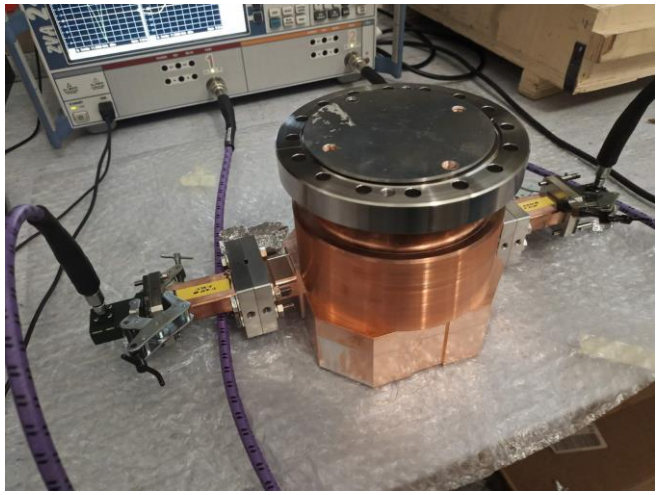
# RF measurement of the Bowl cavity before final brazing

| | Open | Short |
|---|---|---|
| Measured | 11989.740 | 11989.715 |
| Vacuum | 11992.916 | 11992.892 |
| Scaled to 30 ℃ | 11991.836 | 11991.811 |
| Scaled to 20 ℃ | 11993.875 | 11993.850 |

| | Frequency [MHz] | $Q_0$ | $Q_e$ | Beta |
|---|---|---|---|---|
| Mechanical | 11993.9 | 7.45e4 | 2.74e4 | 2.72 |
| Open (Vacuum) | 11991.836 | 6.08e4 | 2.72e4 | 2.234 |
| Closed (Vacuum) | 11991.811 | 6.88e4 | 2.70e4 | 2.55 |



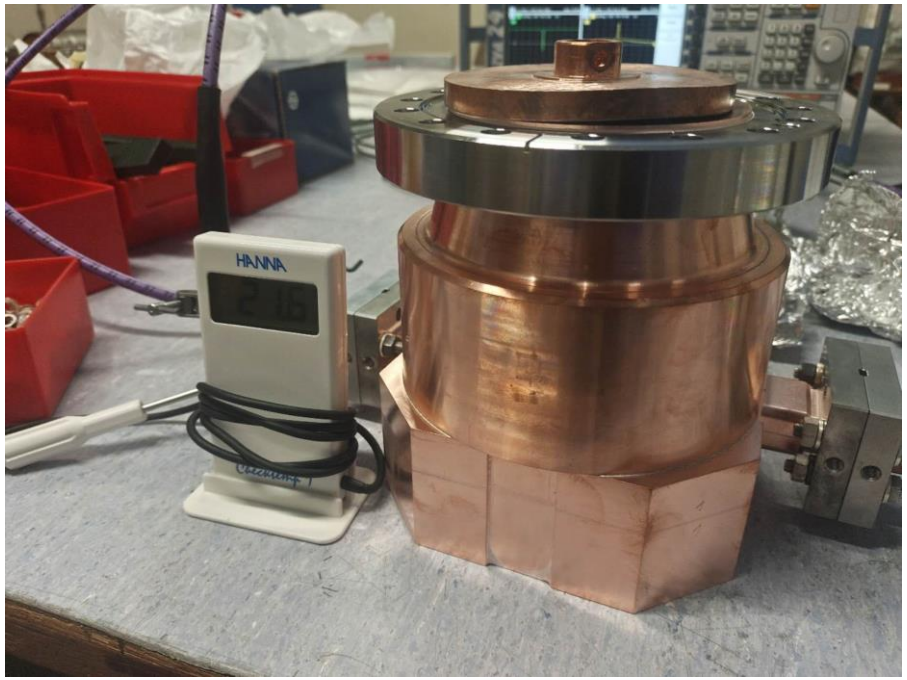



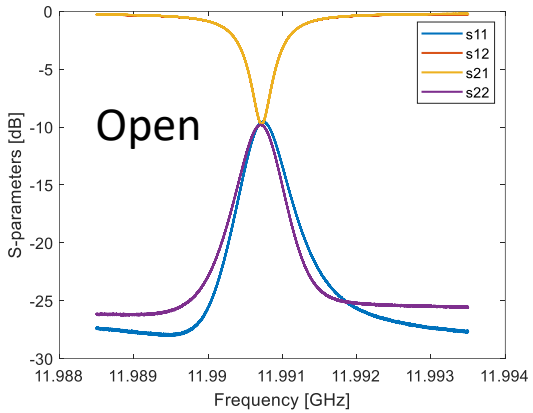


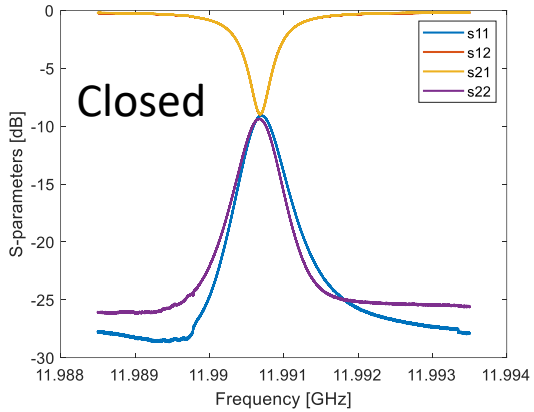
**Temperature: 24.7 ℃**

# RF measurement of the Bowl cavity after final brazing

- Reflection is increased after the final brazing



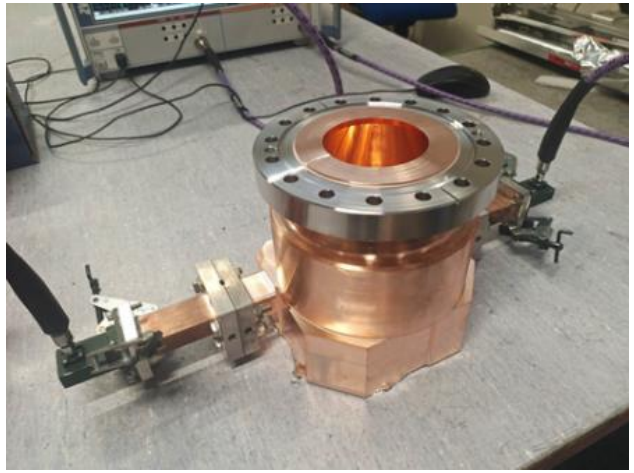

| Summry | Design | Closed Before. | Closed After. | Open Before. | Open After. |
|---|---|---|---|---|---|
| Frequency [MHz] | 11994 | 11994 | 11994 | 11994 | 11994 |
| Temperature [°C] | ---- | 20.0 | 20.8 | 20.0 | 20.8 |
| Q0 | 7.47e4 | 6.88e4 | 6.88e4 | 6.08e4 | 6.35e4 |
| Beta | 2.72 | 2.55 | 2.59 | 2.34 | 2.36 |
| S11 @ f0 [dB] | -59.7 | -22.6 | -9.4 | -22.0 | -9.6 |
| S11 @ f0+1MHz [dB] | -48.0 | -38.4 | -24.6 | -39.2 | -24.2 |
| S11 @ f0-1MHz [dB] | -48.0 | -41.1 | -28.3 | -40.0 | -27.7 |

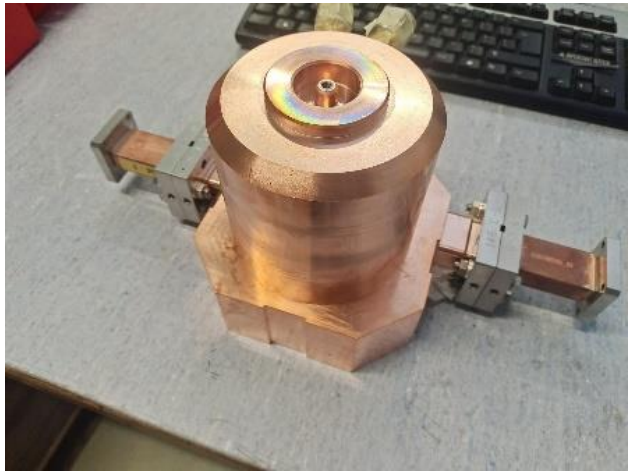
# Outline

- Background
- RF design of the CLIC-K module
- RF measurement of the BOC pulse compressor
- RF measurement of the bowl cavity
- **Summary**

# Summary

- We designed a new  RF module for klystron-based CLIC
- We fabricated and measured two prototypes for BOC pulse compressor and bowl cavity
- Metrology and analysis will be done for the two prototypes
- The spherical pulse compressor will be measured and analyzed






Thanks for your attention !!!