Beam Breakup limit estimations and higher order mode characterisation for MESA

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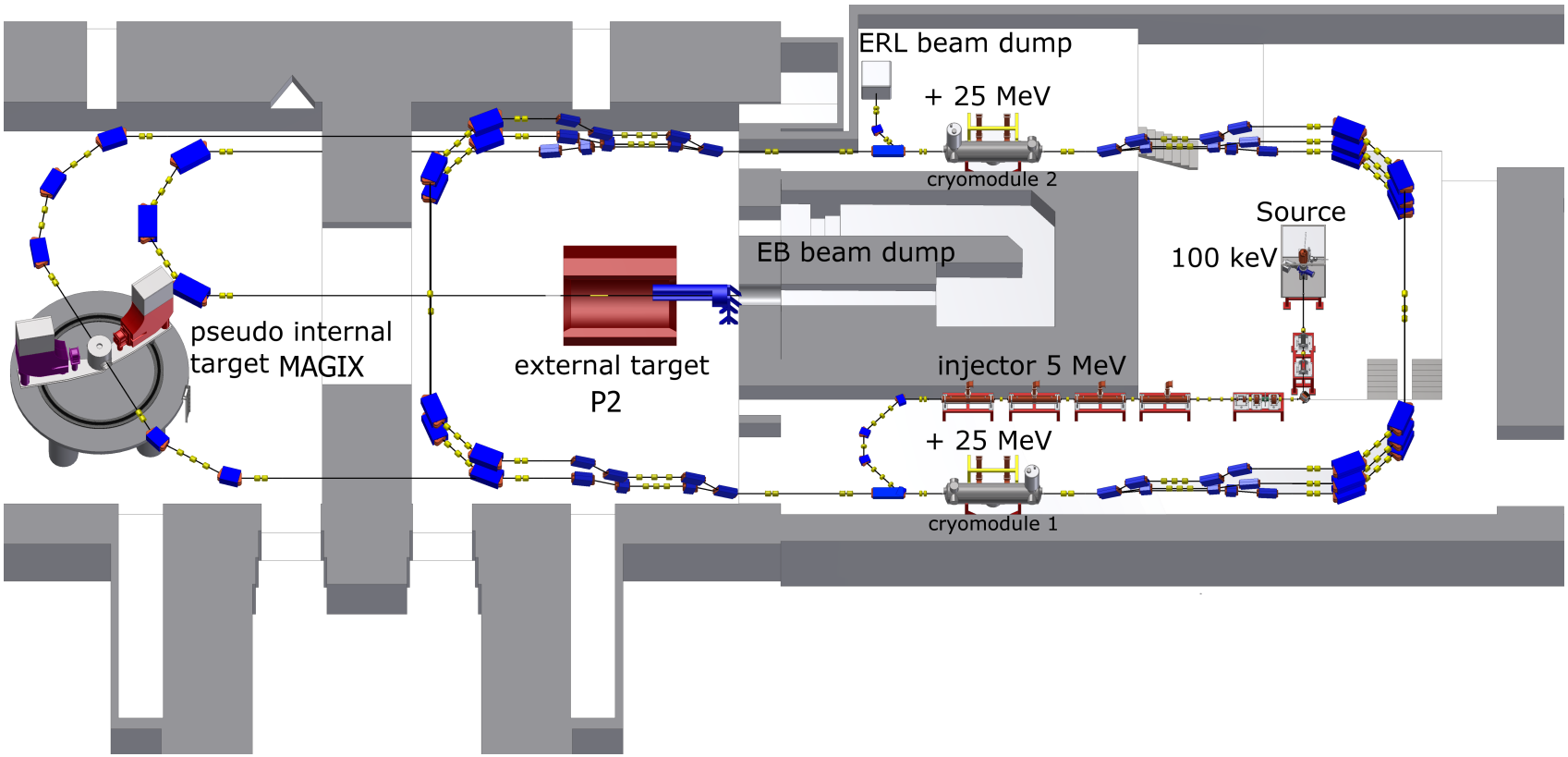
PRISMA+ ACCELENCE

Mainz Energy-Recovering-Superconducting Accelerator



Picture by D. Simon, T. Stengler

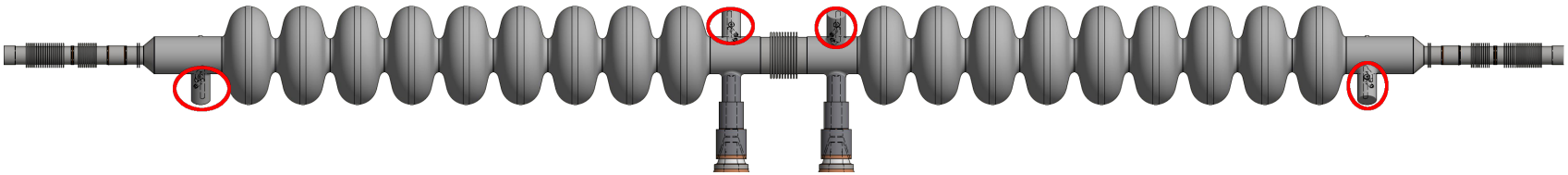
Motivation

- Transverse Beam Breakup limits of MESA
- Injector to end tracking for MESA ER mode
- HOM spectra and behaviour from cavity to dressed module
- Learn some new codes on the way

Accelerator codes at MESA

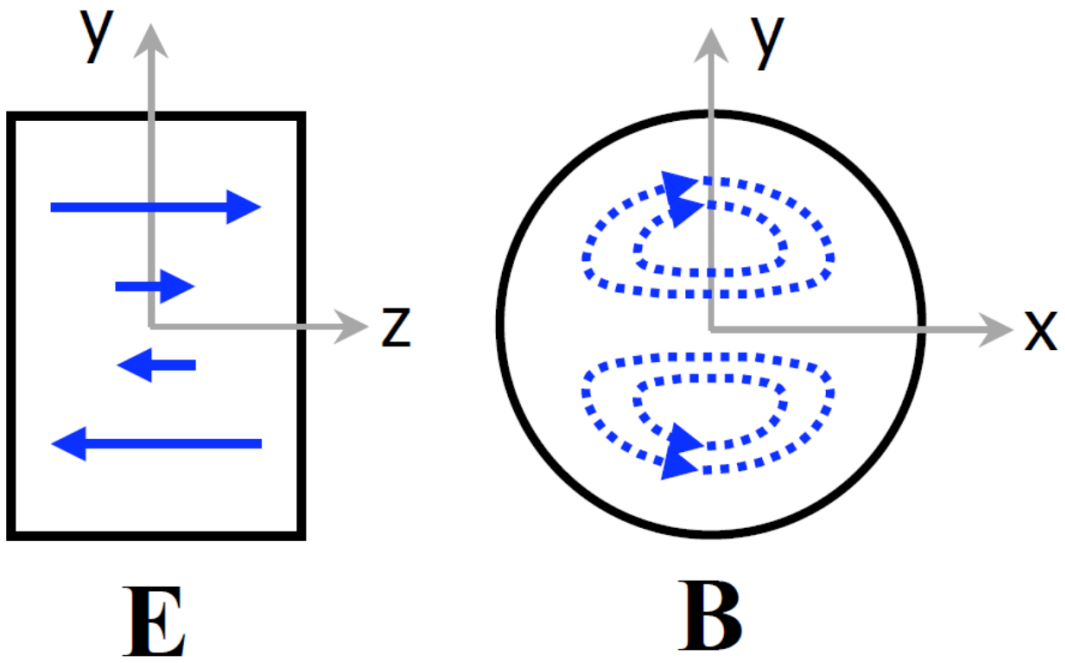
- Source Design: CST (S. Friederich)
- MELBA: Parmela, CST, Parmela, CST, Parmela, CST (C. Matejcek, P. Heil)
- MAMBO: CST, Parmela (R. Heine)
- MARC0: Beamoptix matrix code, CST (S. Heidrich), later ELEGANT (Khan/Stoll)
- MEEC1/2: Parmela (D. Simon), later ELEGANT (A. Khan)
- MARC1 to MARC5: Beamoptix and MADX (D. Simon), later ELEGANT (C. Stoll)
- Internal gas target interaction with beam: GEANT4 + BDSIM (B. Ledroit)
- BBU: BI code by Ivan Bazarov (C. Stoll)

ELBE type cryomodule



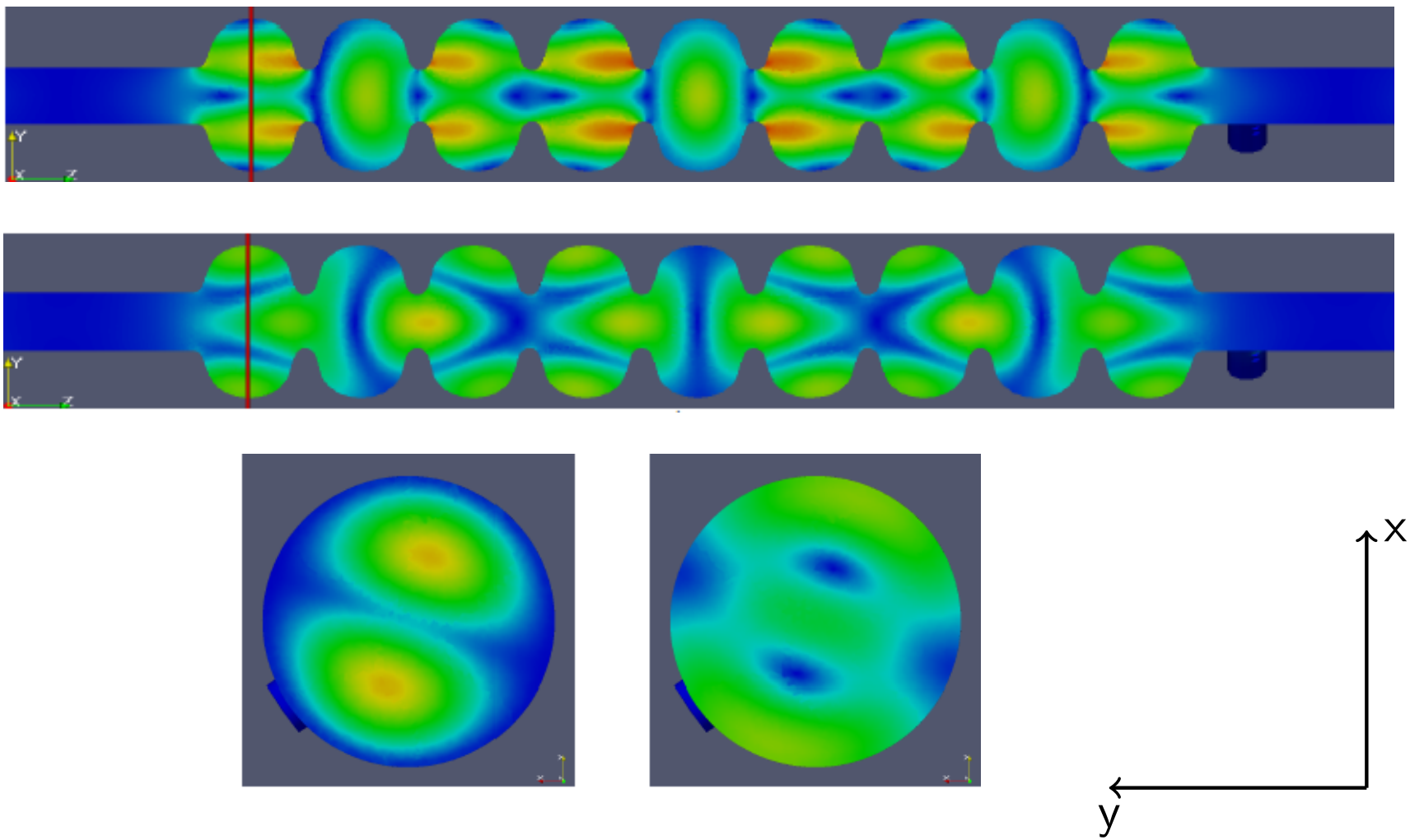
- Two 1.3 GHz TESLA type 9 cell cavities
- 4 Higher Order Mode (HOM) couplers per module
- Operated at 1.8 K

Dipole Higher Order Modes



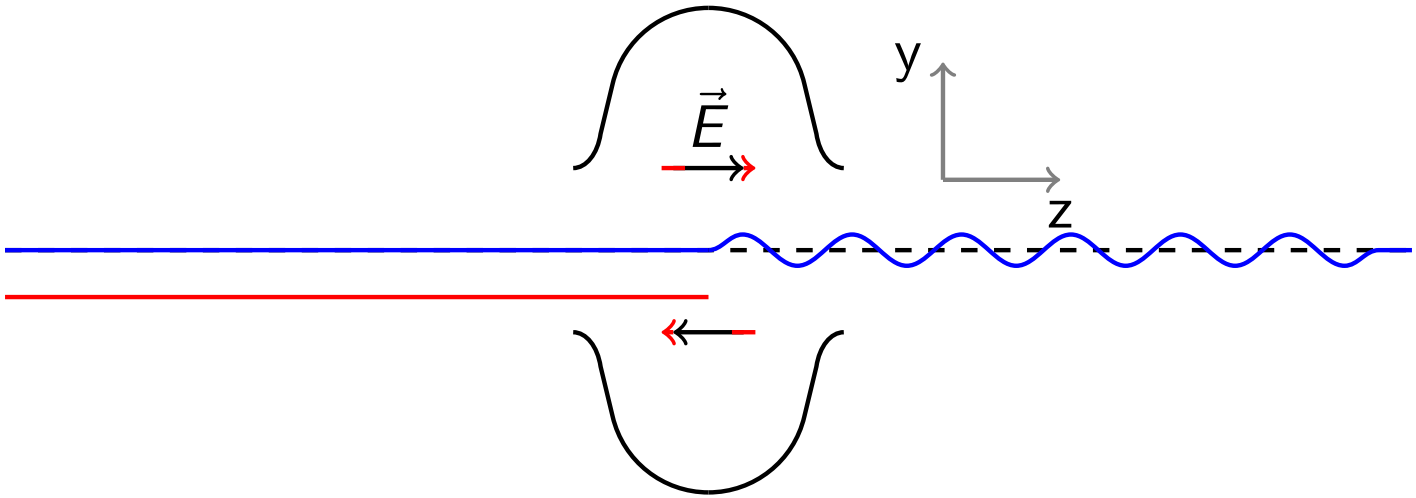
- TM110 - like modes
- Beam can exchange energy via off axis electric field
- Bunch is deflected by transverse magnetic field component

Dipole Higher Order Modes



Picture: Eigenmode Calculations for the TESLA Cavity Considering Wave-Propagation Losses through Fundamental and Higher-Order Mode Couplers

Transverse beam breakup



$$I_{\mathrm{th}} = \frac{-2p_r c}{e\left(\frac{R}{Q}\right)_m Q_m k_m M^* \sin(\omega_m t_r)}$$

$$M^* = M_{12}\cos^2(\alpha) + (M_{14} + M_{32})\cos(\alpha)\sin(\alpha) + M_{34}\sin^2(\alpha)$$

Measurement Setups

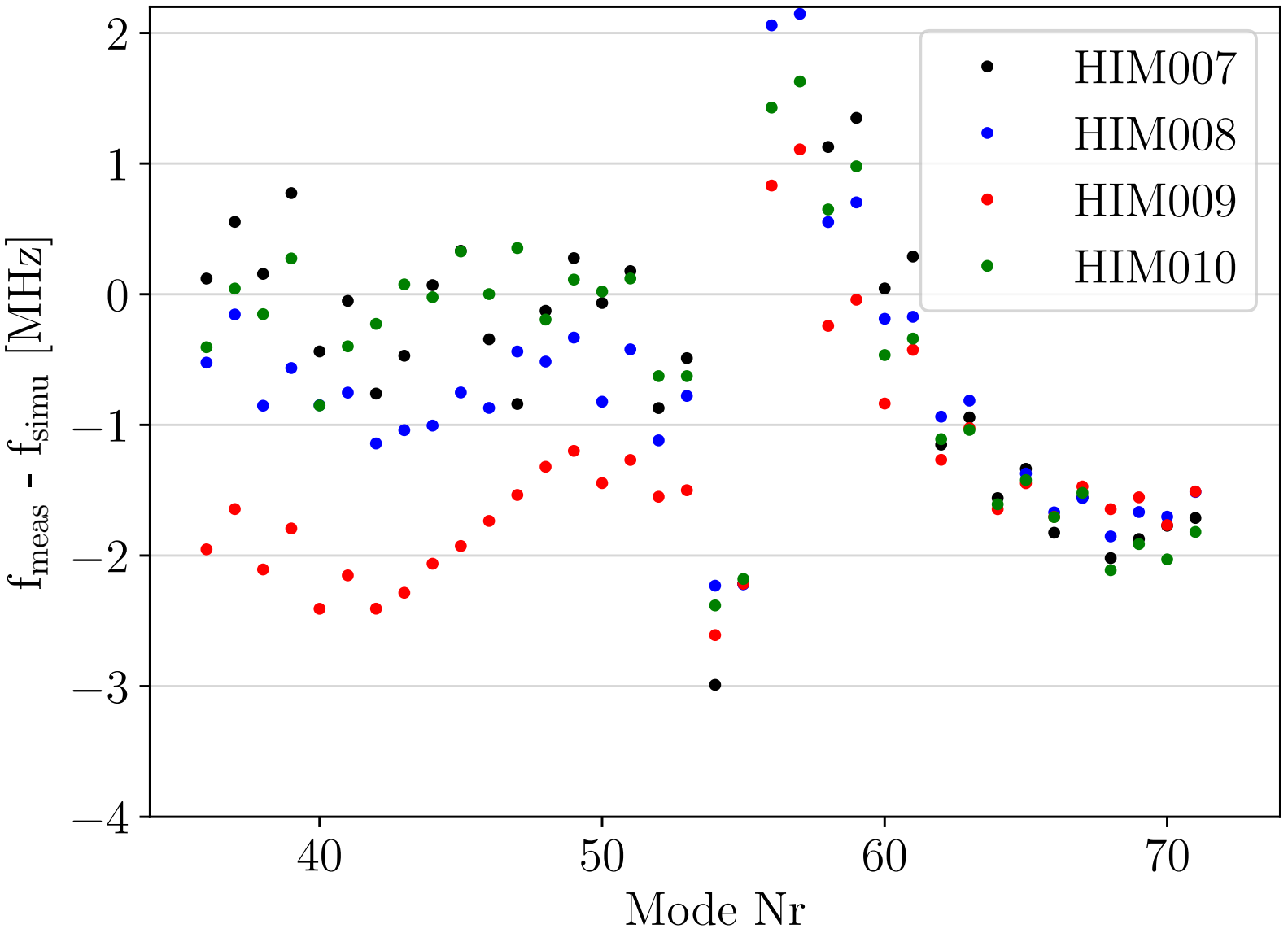
Measurements at DESY

- Single cavity in 2 K vertical cryostat
- First 2 passbands of HOMs measured $\rightarrow$ 18 modes with 2 polarisations each
- Setup as was used for TESLA cavity quality control

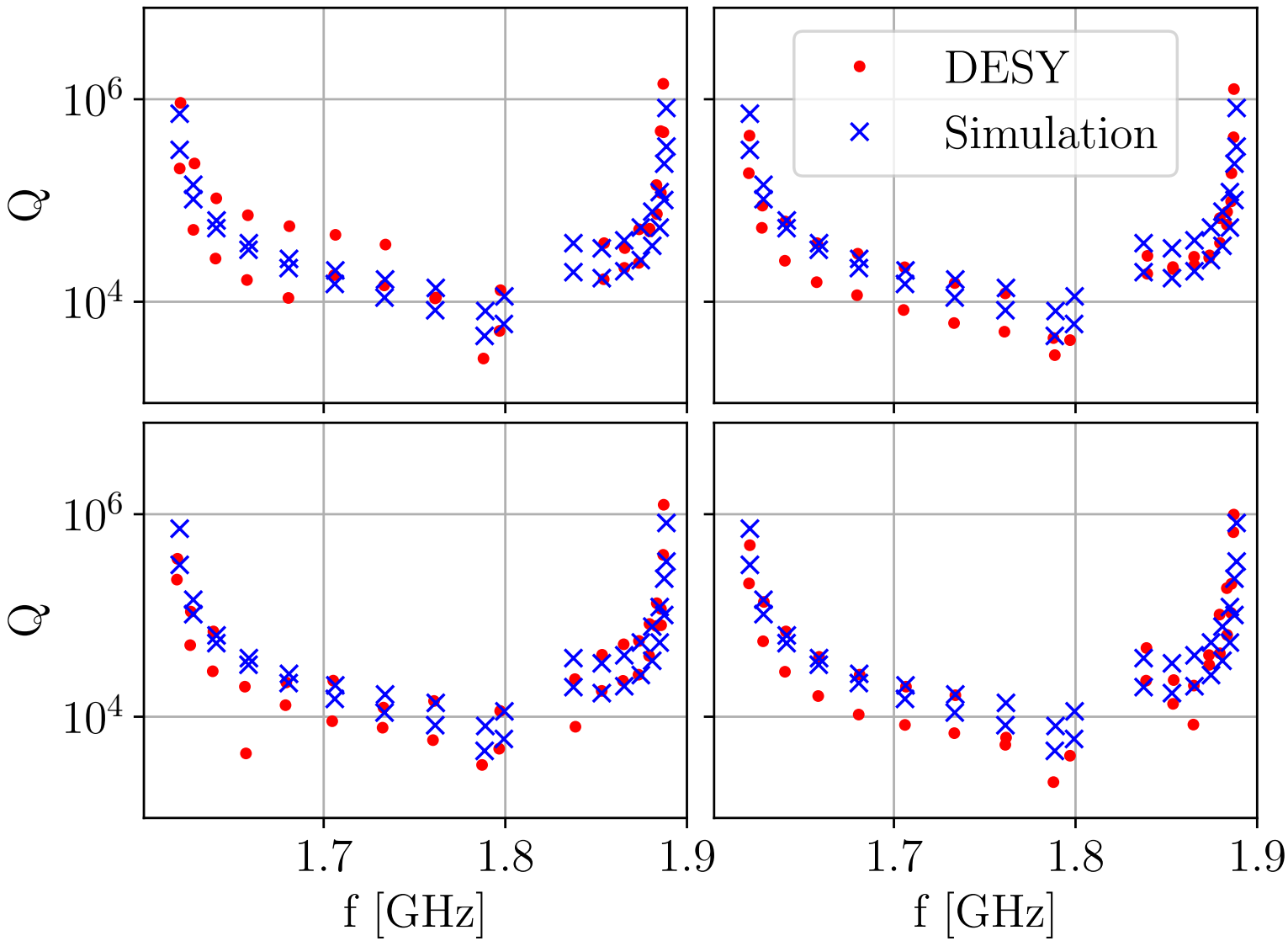
Measurements at HIM

- Two cavities fixed in a cryomodule and tuned to 1.3 GHz fundamental mode @ 2 K
- First two passbands of HOMs measured $\rightarrow$ 36 modes
- NWA measures HOM coupler output, excited at power coupler

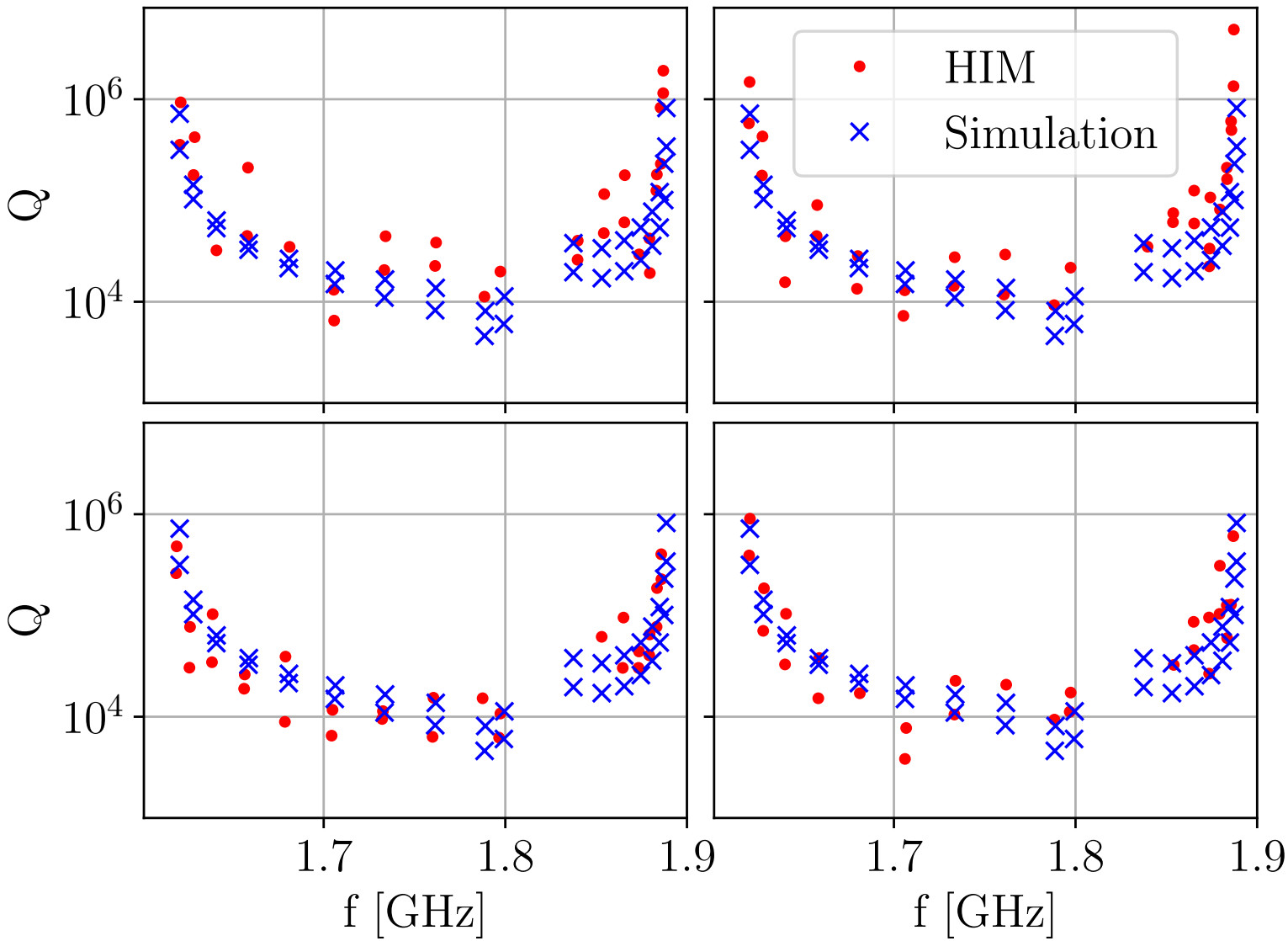
HOM frequency deviation



HOMs of undressed cavities



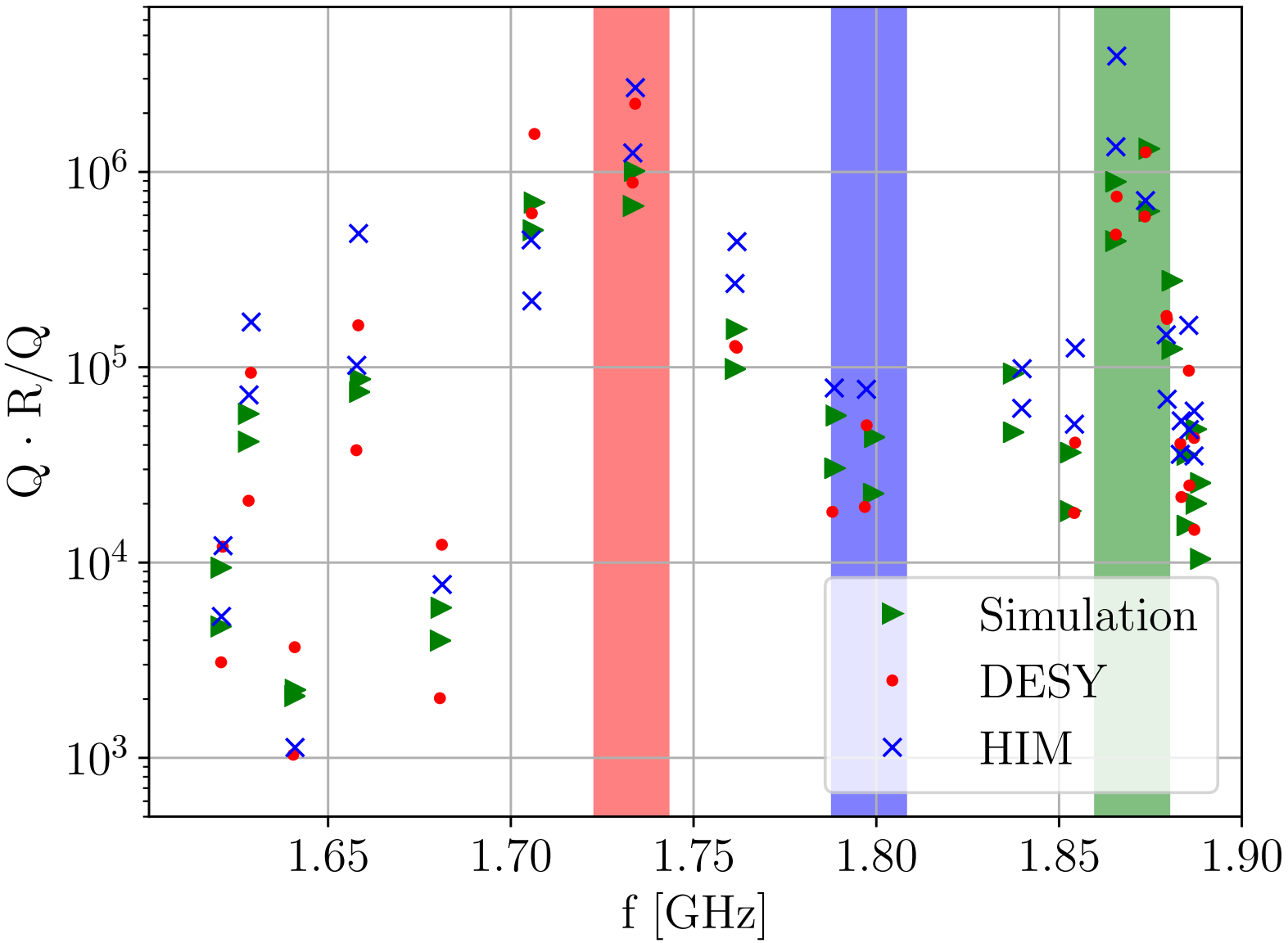
HOMs dressed to module



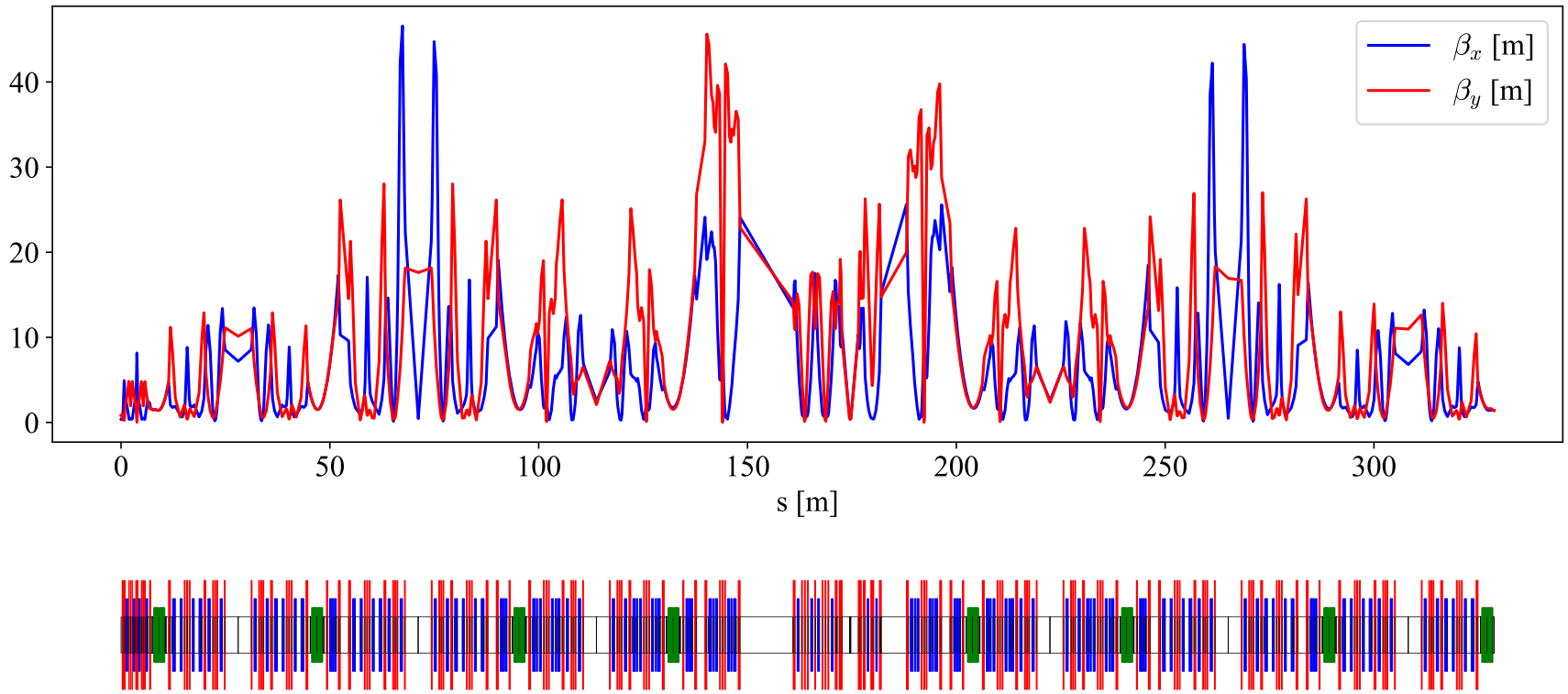
Measurement results and interpretation

- Frequency deviation $\rightarrow$ tuning to fundamental mode shuffles HOM frequencies
- Frequency spread between cavities $\rightarrow$ fabrication tolerances
- Larger Q spread $\rightarrow$ deviation from elliptical shape
- Higher Q factor $\rightarrow$ deviation from the HOM coupler gap width compared to simulated geometry

Bandwidth comparison

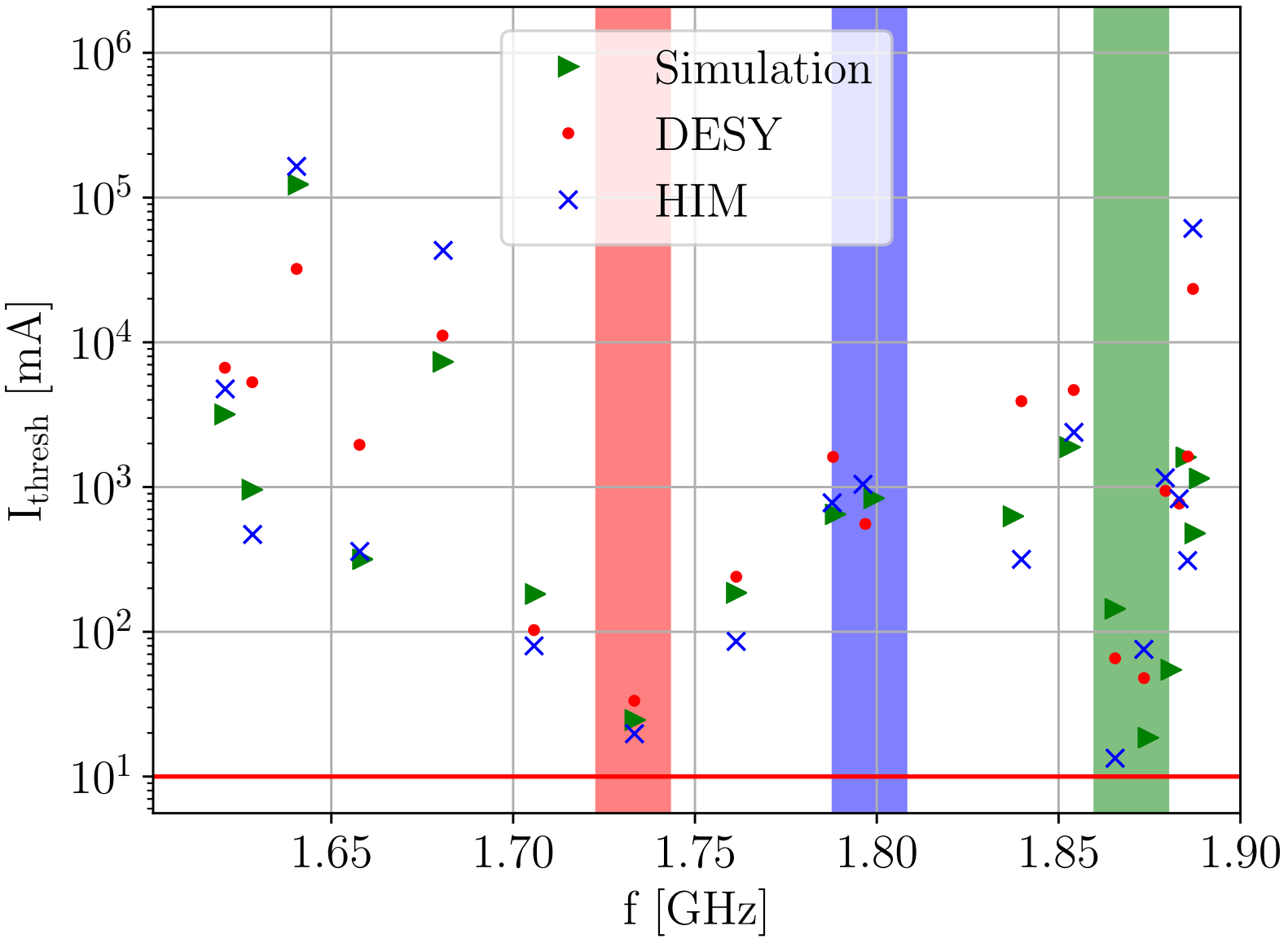


ER lattice setup



ER lattice ready for tracking and BBU studies

BBU limited threshold current for MESA



Conclusion and outlook

Conclusion

- HOM spectra and bandwidth measured
- Deviations from simulation results expected and explicable
- Threshold current limit simulated 13.38 mA

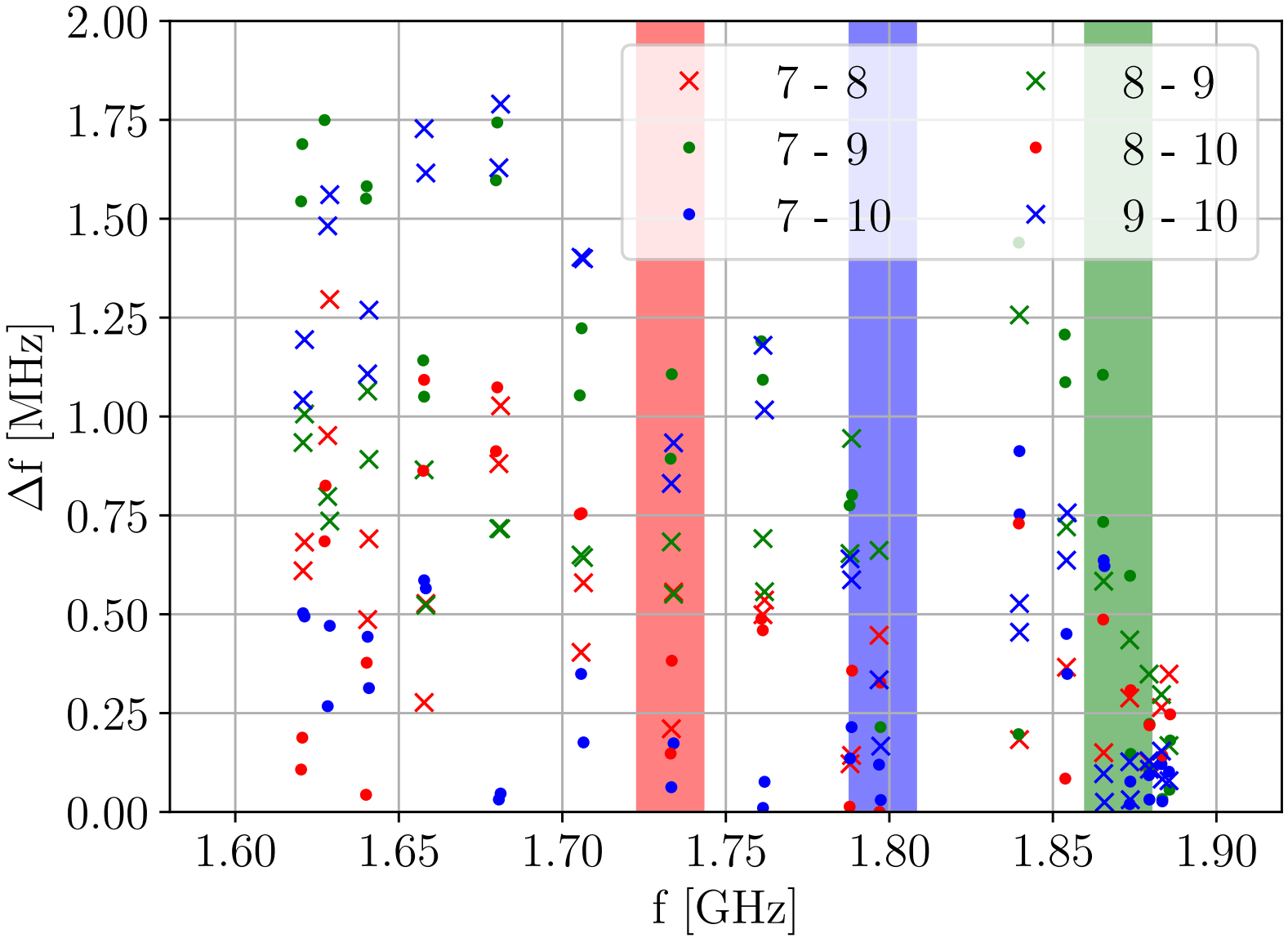
Outlook

- Investigation of MESA beam current limits due to HOM coupler heating
- Further inspection of HOM behaviour while cryomodule is incorporated at BERLinPro
- Implementation of lattice modifications, work flow established

Thank you for your attention!

Special thanks to A. Khan, T. Stengler, D. Simon, F. Hug, S. Thomas
Thanks to the whole MESA project team!

HOMs of undressed module



HOMs of dressed cavities