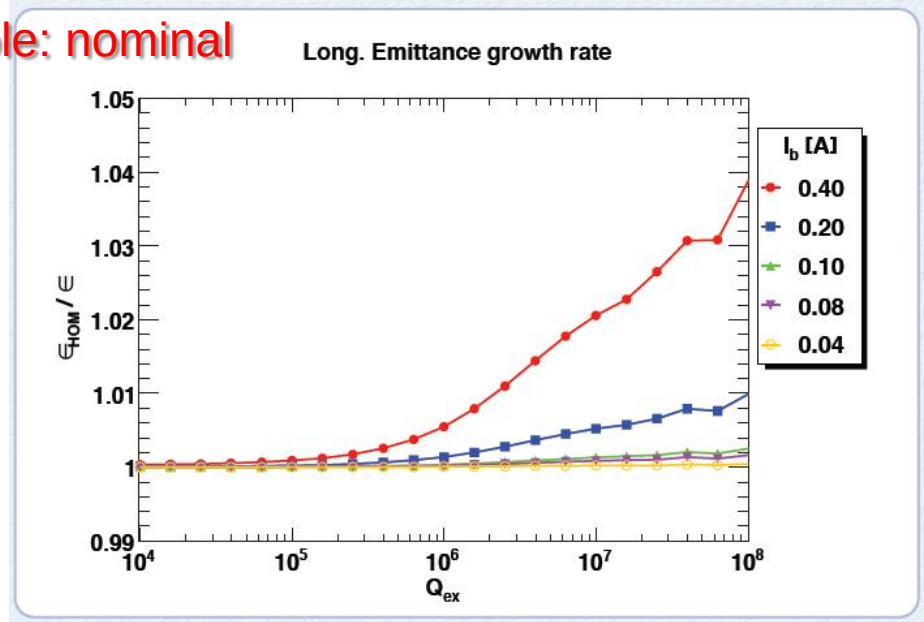
# Longitudinal HOM damping *estimations* for SPL cavity. status

W. Weingarten

# What Q do we need wrt deposited power and beam break up simulations under various conditions for whole linac?

$Q_{ex}$ limits based on beam dynamic simulations
Simulated cases: nominal, RF errors, chopped beams, fundamental pass-band modes

Example: nominal




- one HOM with max R/Q in each cavity pressent.

**Overall conclusion:**

To be on the save side and keep all operation options open a $Q_{ex} = 10^5$ is recommended!

Marcel Schuh / CERN-BE-RF

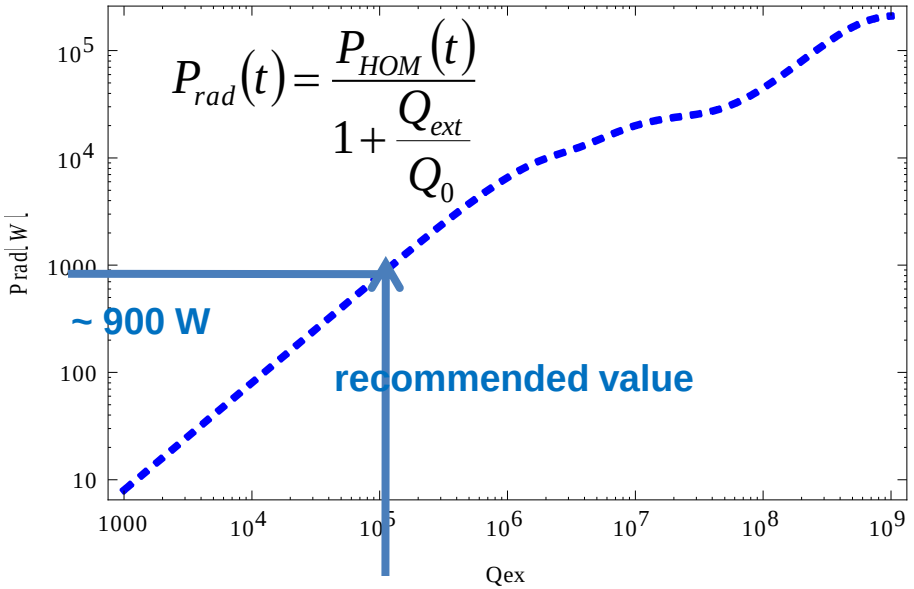
# What is the longitudinal HOM power for pulsed beams to be dumped into the HOM load/cavity?

shown at 4th SPL Collaboration Meeting - jointly with ESS at LUND (Sweden)

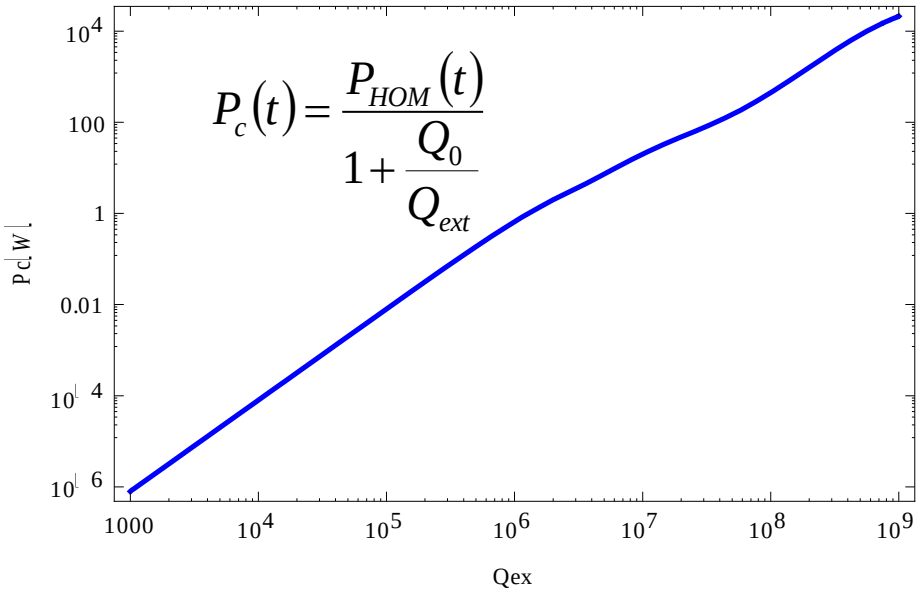
***f* (HOM) precisely on beam spectral line**

$I$ = 40 mA; pulse length 1 ms, $R/Q$ = 100 Ω ; rep. rate 50 Hz; $f_{HOM}$ **= 2.1 GHz**; $Q_0 = 10^{10}$

radiated power to HOM load




dissipated power in cavity

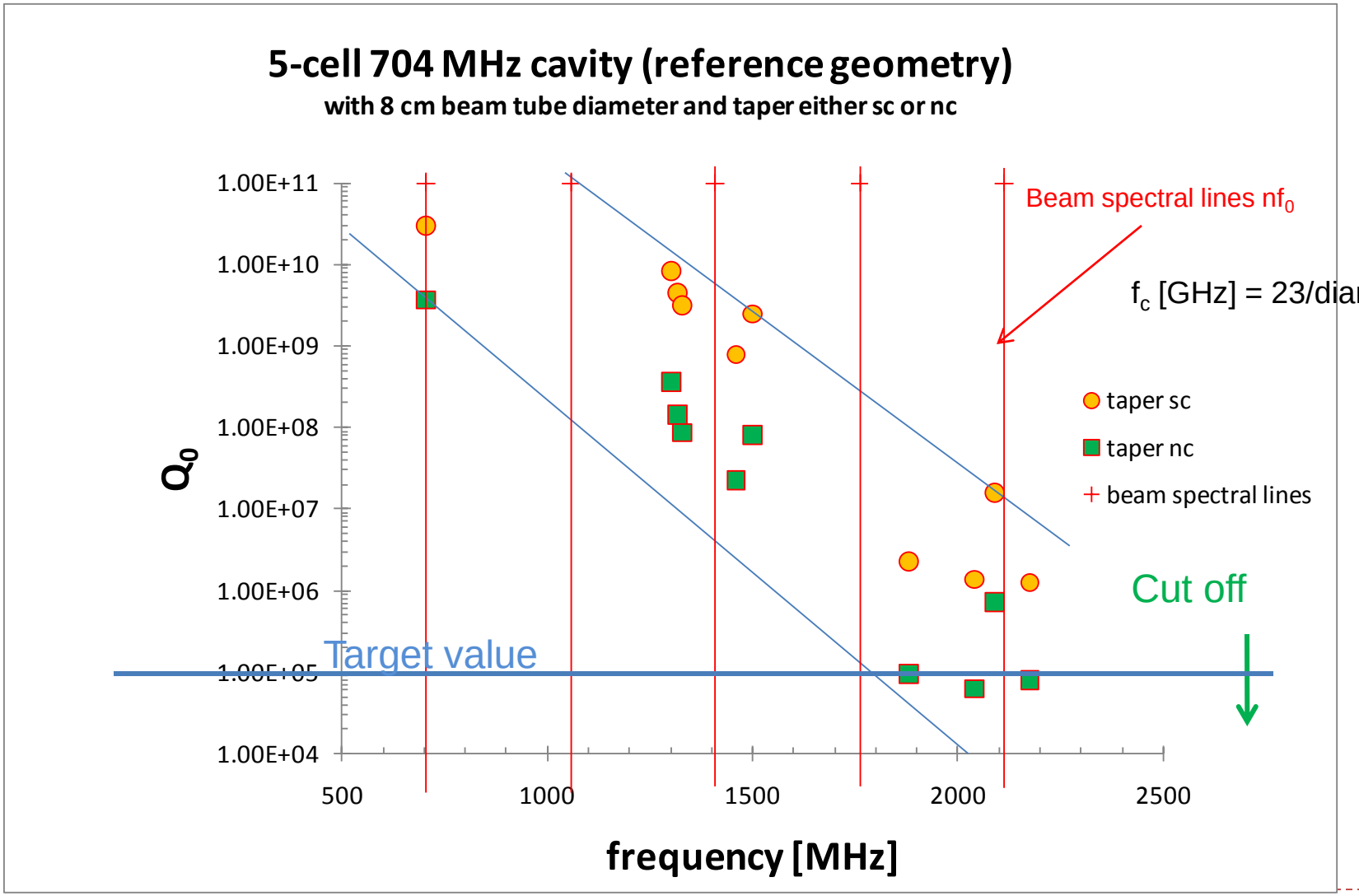



The main beam Fourier components (n·352 MHz) contribute significantly to the HOM power, the 50 Hz Fourier component, however, only marginally; to reduce the HOM power below 100 W, **the Q-value of the HOM must be $Q < 10^4$**

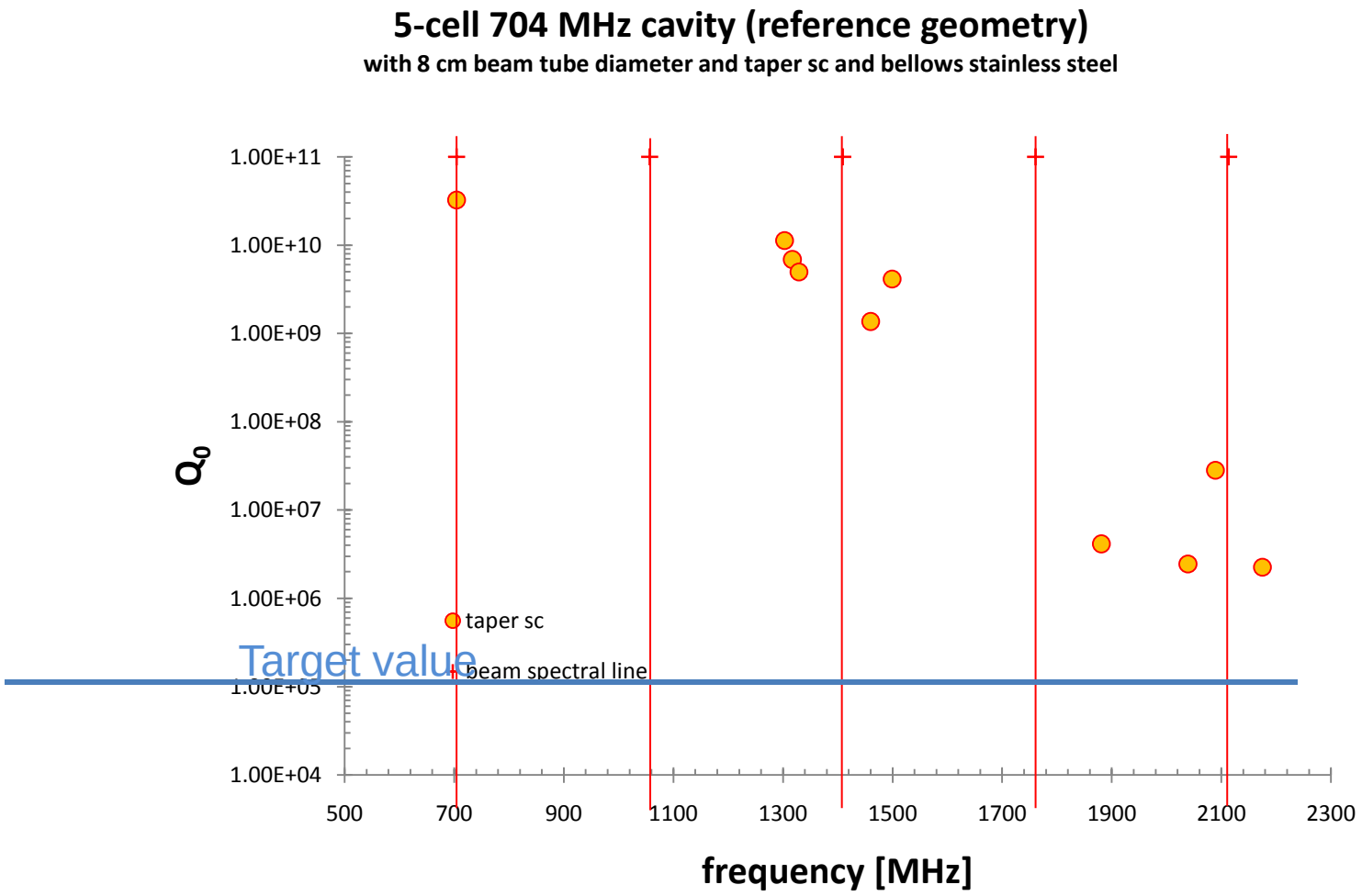
# Various HOM damping schemes 1/5

## (already shown in SPL cavity WG meeting on 8 March 2010)

## damping by beam tube OR beam tube & taper made of high Al iron



# Various HOM damping schemes 2/5
## via beam tube made of stainless steel



# Various HOM damping schemes 3/5

## via beam tube made of stainless steel

by Karol Krizka/University of Toronto and summer student at CERN: Technical Note, SPL cavity: Power dissipated at bellows, 9 July 2010

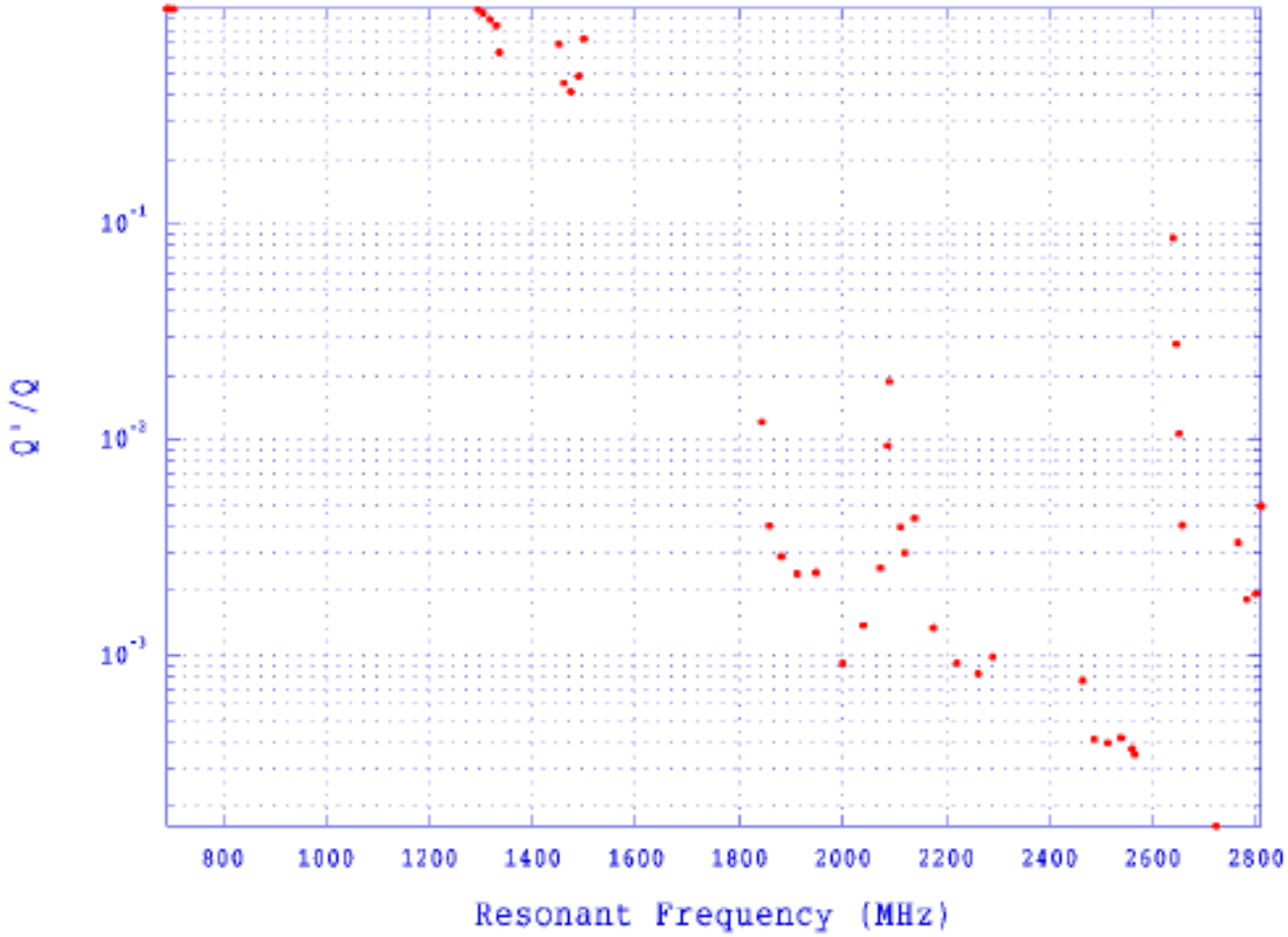


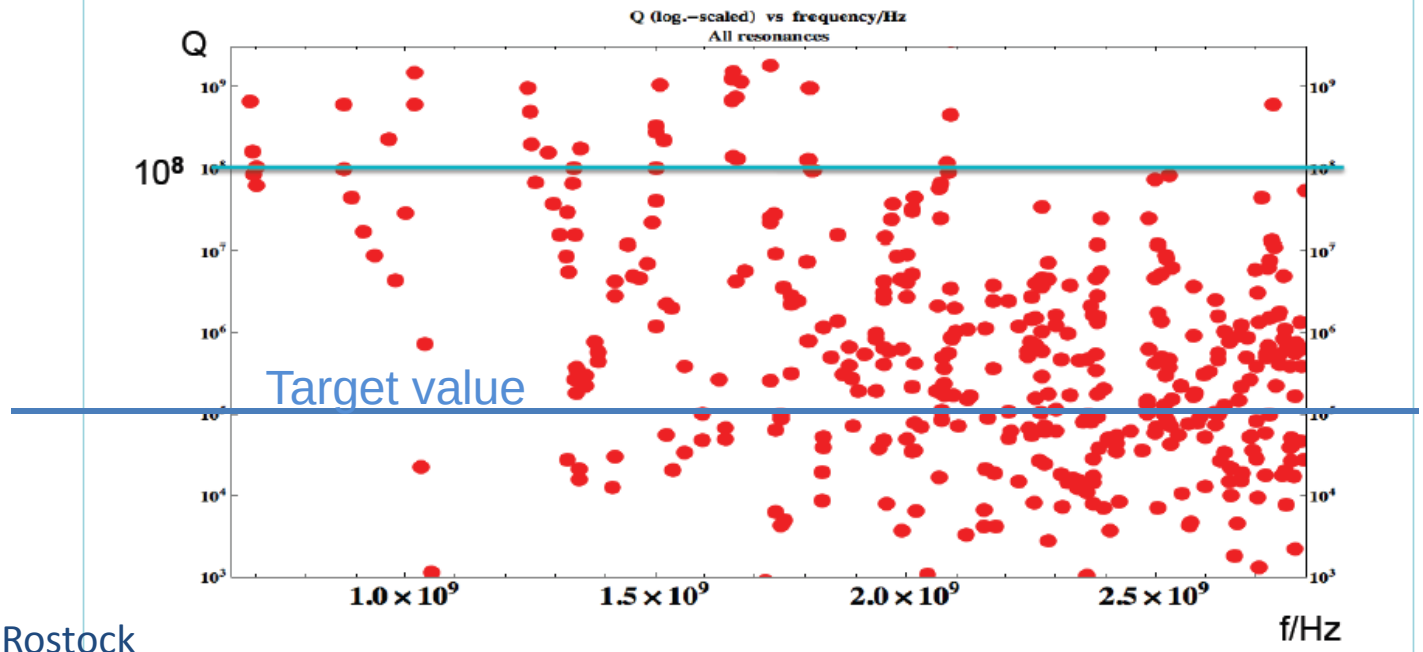

Figure 3: Change in cavity efficiencies between making the bellows superconducting and made out of stainless steel.

# Various HOM damping schemes 4/5

## via coaxial antenna

shown at 4th SPL Collaboration Meeting - jointly with ESS at LUND (Sweden)

Q-value spectrum for 0 mm antenna depth:




by far to heavy loading of fundamental mode => ...

Hans-Walter Glock/Uni Rostock

... the main message remains:

Pick-ups without fundamental mode filters will not be able both to preserve fundamental mode Q and damp all HOMs sufficiently.

Confirmed by Wolfgang Weingarten's 2D computations using beam pipe dampers.

# Concluding remarks 2/2

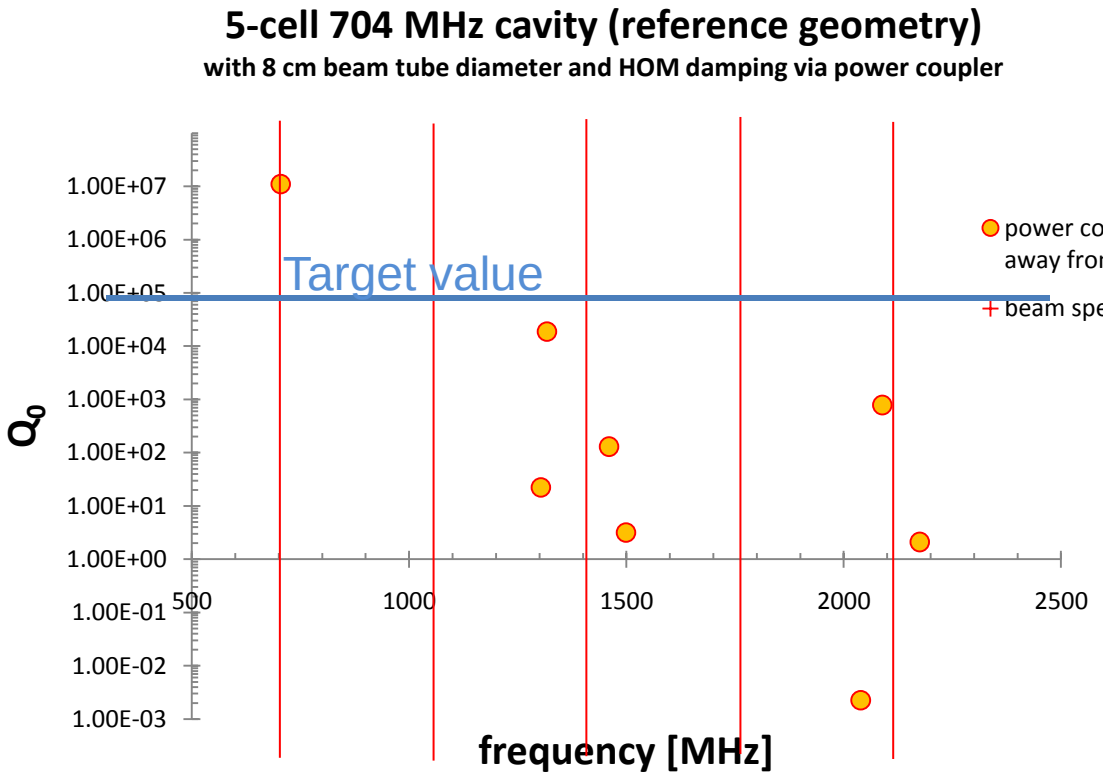
shown at 4th SPL Collaboration Meeting - jointly with ESS at LUND (Sweden)

- Pros and cons of alternate designs of the end group with regard to the deposited **HOM power** were discussed; no follow up possible (by now) due to time constraints
  - At the recommended $Q = 10^5$, the beam deposited power into the HOMs can achieve ~ 1 kW
  - Cures to reduce the beam deposited power consist in
    - avoiding the beam Fourier components by at least 10 kHz with a Q-value $Q > 10^7$ or
    - damping the HOMs to below $Q = 10^4$
  - The previous idea (HOM workshop) of damping the HOMs by a normal conducting (nc) beam tubes and additional coaxial antennas (without filter) does not survive;

    however, damping by nc beam tubes turns out to be efficient above 1800 MHz (the damping action of the power coupler not yet included!)
  - **Hence if we want to damp the HOMs equivalently to a Q-value of $10^5$ or even stronger, we should envisage notch filter type HOM couplers**
- A reference design of the **magnetic shielding** exists
- The **cavity** and **cryogenic parameter** list was updated
- The build-up of the CERN **EP installation** is progressing

*However, if the design shall be compatible with various chopping schemes, this option is excluded (c.f. Marcel S. presentation today)*

# Various HOM damping schemes 5/5
## via power coupler ?




$$Q_L = Q_0 \cdot \frac{1}{1 + \frac{P_{ant}}{P_c}}$$

$$P_{ant} = \frac{1}{2} \cdot Z_0 \cdot I^2$$

$$I = j \cdot \pi r_i^2$$

$$j = \omega \varepsilon_0 E$$

***These numbers are only estimations !***

# What heat is dissipated in ss bellows?

$$P_{rad}(t) = \frac{P_{HOM}(t)}{1 + \frac{Q_{ext}}{Q_0}} \qquad P_c(t) = \frac{P_{HOM}(t)}{1 + \frac{Q_0}{Q_{ext}}}$$

- **Fundamental mode:** Heat dissipation in cavity @ 704 MHz, 25 MV/m, $Q_0 = 10^{10}$: **$P_c$ = 123 W CW => 5 … 16 W pulsed**
- Heat dissipation in SS bellows @ 704 MHz, 25 MV/m, equivalent $Q_0 = 3 \cdot 10^{11}$:

  **$P_c$ = 4 W CW => 0.04 … 0.13 W pulsed**
- **HOM:** Heat dissipation in SS bellows @ 2112 MHz, $Q_0 = 2.5 \cdot 10^7$;

  construct HOM damper with $Q_{ext} < 10^5$ or/and

  count on damping by power coupler: $Q_{ext} < 10^4$ (**to be checked!**)

**Under these assumptions the heat dissipated in the SS bellows for the HOM at 2.112 GHz is less than 3 W (worst case).**

**For the bellows made of copper, this number would be more than a factor 32 less[1].**

[1] $R_s$ (OFHC Cu) @ 500 MHz = 1 mΩ, CERN-1992-03,p. 320, $\rho$ (SS) = 51 μΩcm, $R_s = (\pi f \mu_0 \rho)^{1/2}$

# Conclusion

**The conclusion taken at Lund is confirmed:**

**"Hence if we want to damp the HOMs equivalently to a Q-value of $10^5$ or even stronger, we should envisage notch filter type HOM couplers"**

**In addition we may have a chance to damp the HOMs even stronger via the power coupler (simulations should start)**

**The HOM damping scheme by SS beam-tube bellows is proposed to be abandoned; if the damping by the power coupler plus HOM coupler is confirmed to be sufficient, the bellows do not need to be actively cooled by cold He gas (in particular if made from copper).**