L4-RFQ3, version rfq14: spectrum and surface fields

RFQ3 WP11 meeting

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Recap v. rfq13: maximum surface field, gap scaling

Gap scaling normalized E-field calculation for RFQ: $E_{norm} = \frac{V_0}{V_{DC}} \cdot \left(\frac{d_{DC}}{d}\right)^p = E_s^p V_0^{1-p} \cdot \frac{d_{DC}^p}{V_{DC}}$

where V_0 = vane voltage, V_{DC} = 7747 V,
d_{DC} = 100 um, p = 0.72,
E_s = maximum surface field, $d = V_0/E_s$

values in 3D vane design of RFQ3: version rfq13

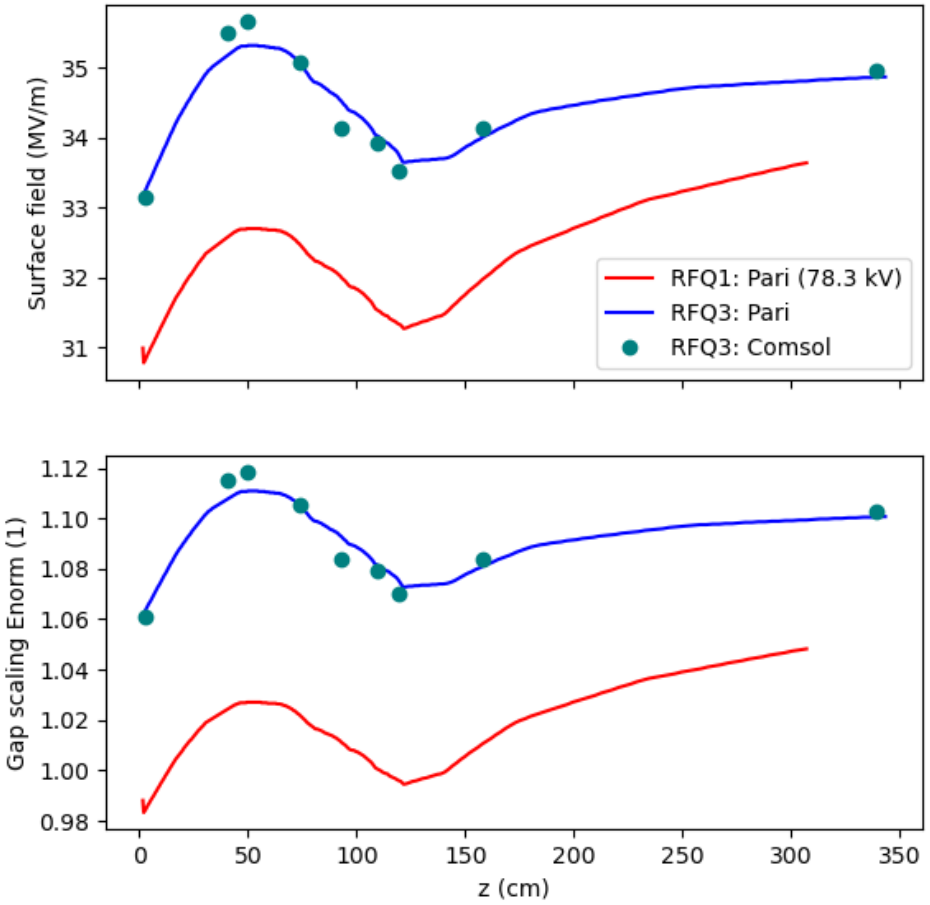
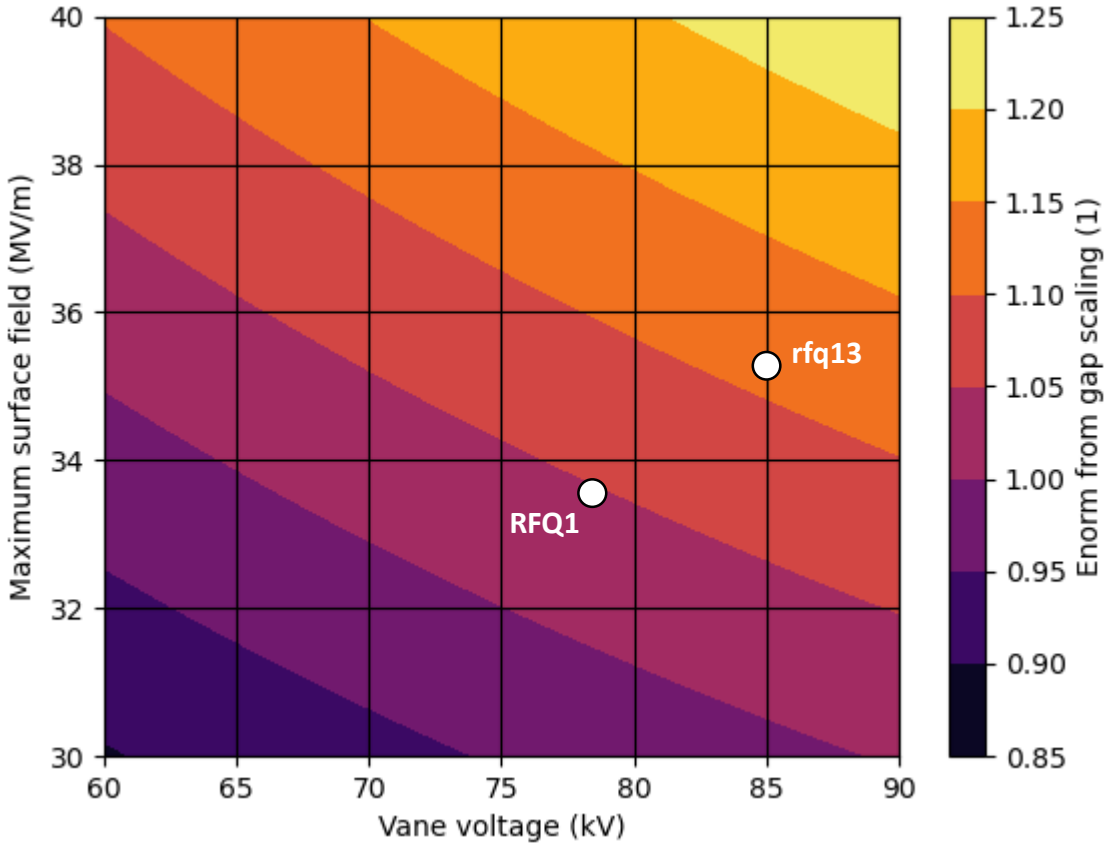


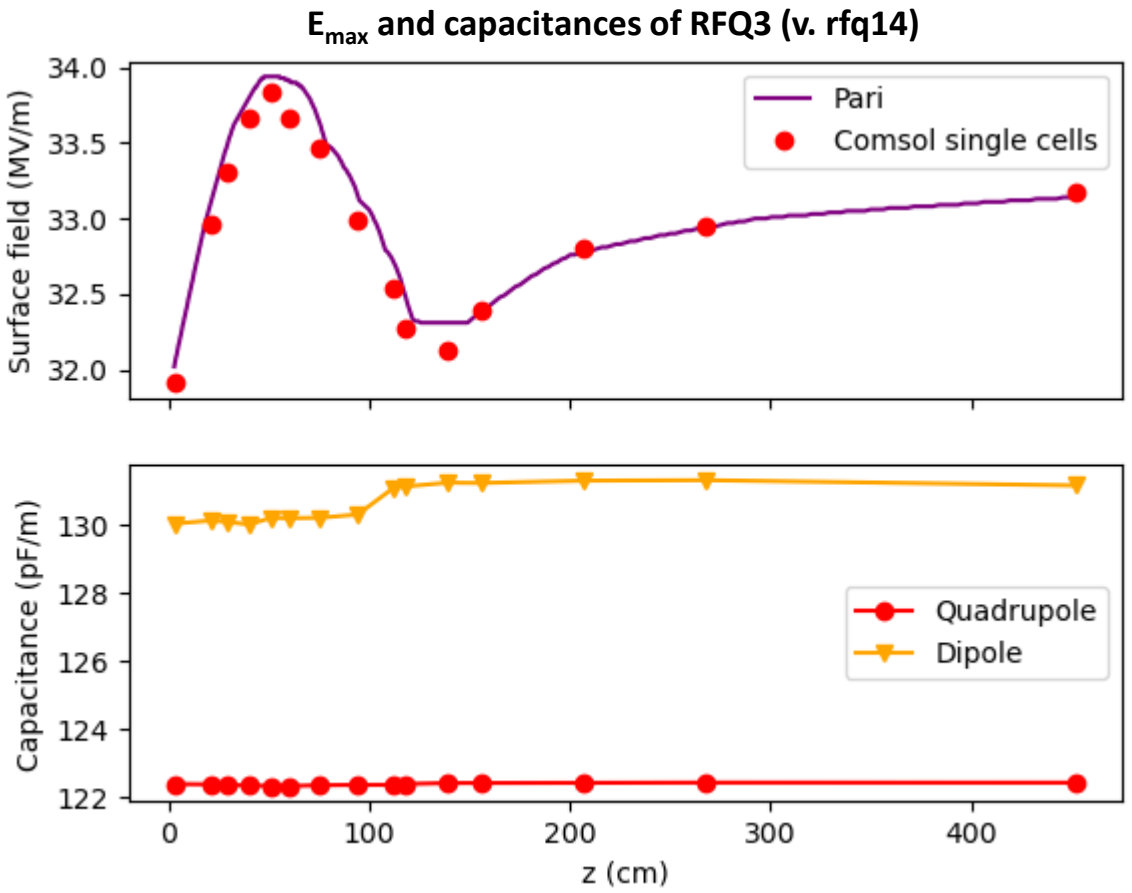
illustration of gap scaling

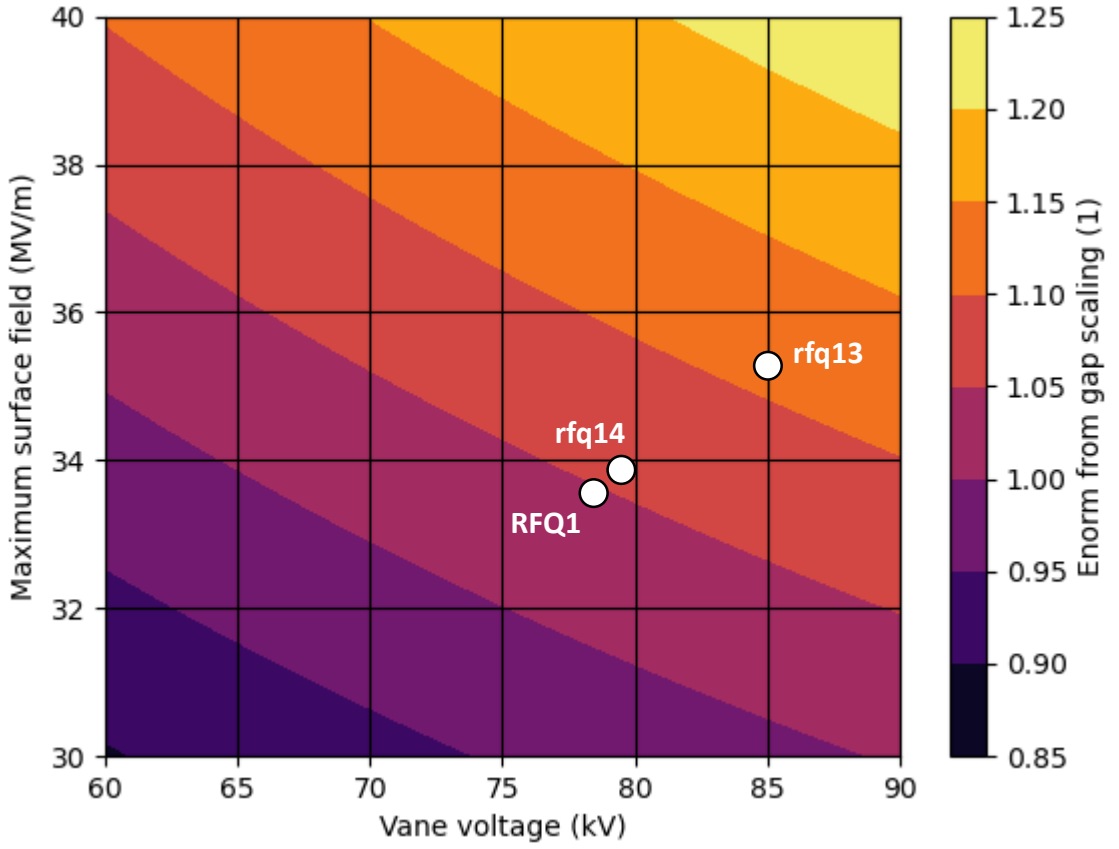
safer if we stay below the RFQ1 value



rfq14: Simulation of individual cells, surface field, gap scaling

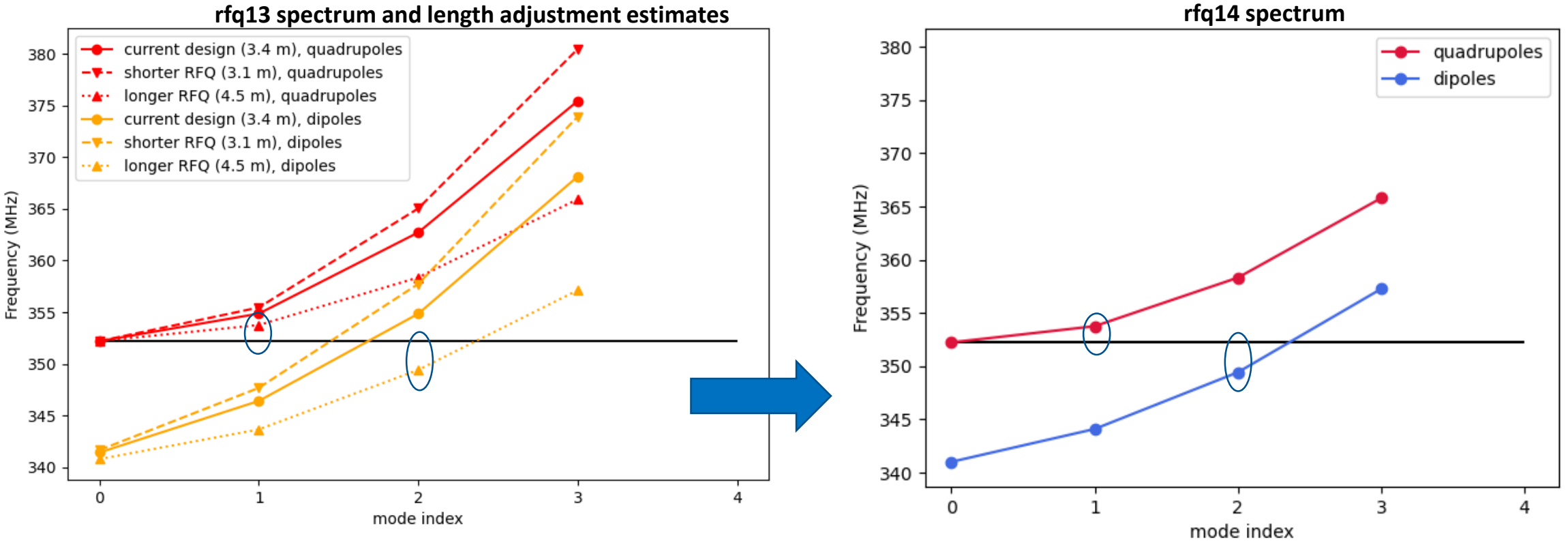
- COMSOL electrostatic (can simulate only vane tips, higher accuracy) → E_{max}
- HFSS rf simulation for capacitance, dipole cutoff, Q-factor → spectrum and power





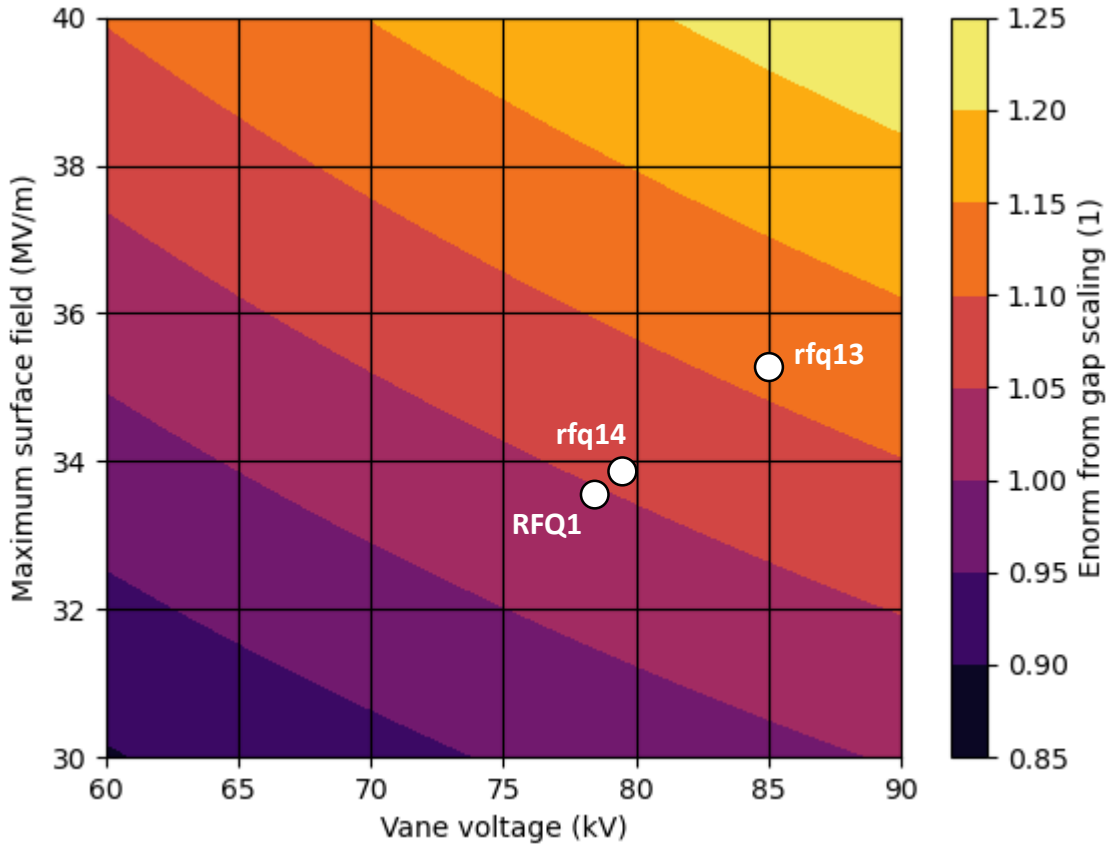
rfq14: spectrum

- Transmission line model for rapid estimate, use end parameters of previous iteration (rfq13)
  (but we have observed that they have little effect on overall spectrum)
- estimated spectrum of 4.5 m long RFQ extrapolated from 3.4 m long RFQ (rfq13) is very close to spectrum
  of actual 4.5 m long RFQ (rfq14), even though modulation etc. is different → this should make iterating beam dynamics and rf easier!
- margins for rfq14 vane design: Q: 1.5 MHz, D: 2.8 MHz (compare rfq13: Q: 2.7 MHz, D: 2.5 MHz)
- actually not much better → make it even longer, or shorter length + dipole rods?



Summary table

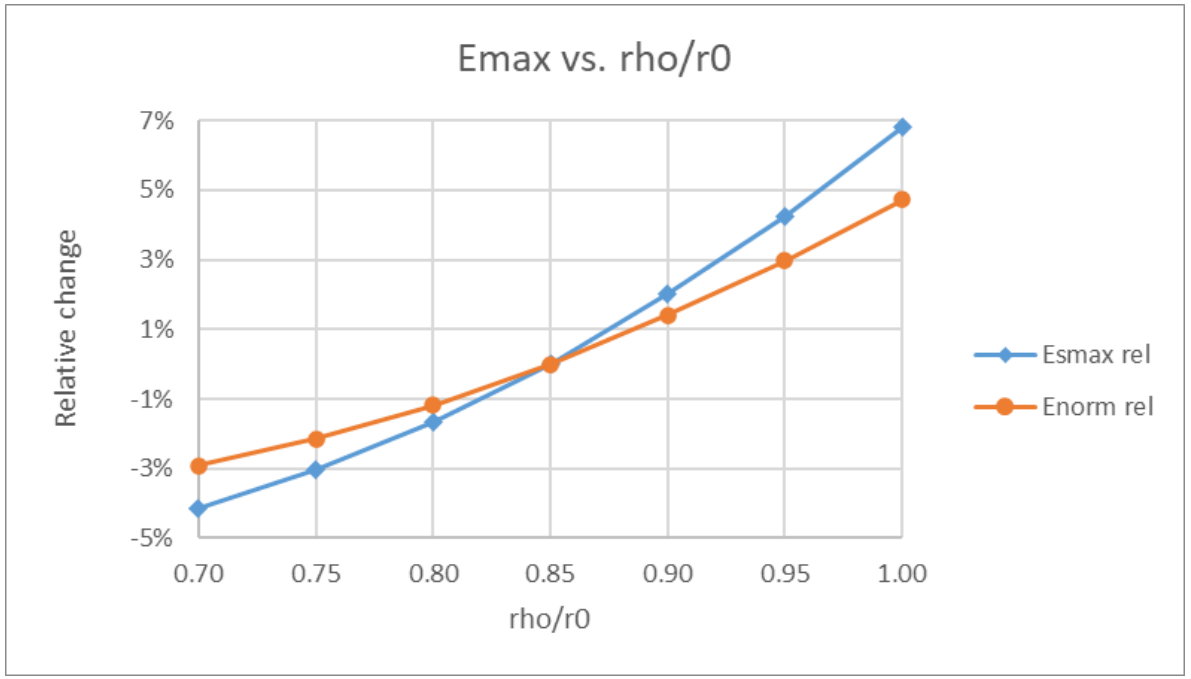
		RFQ1	RFQ3: rfq13	RFQ3: rfq14
Length	m	3.1	3.4	4.5
Voltage	kV	78.3	85.0	79.0
Max. E-field	MV/m	33.6	35.3	33.9
Gap scaling E_{norm}	1	1.05	1.11	1.06
ϱ/r_0	1	0.85	0.85	0.85
$f_{closest\ quadrupole}$	MHz	+3.3	+2.7	+1.5
$f_{closest\ dipole}$	MHz	+2.4	+2.5	-2.8



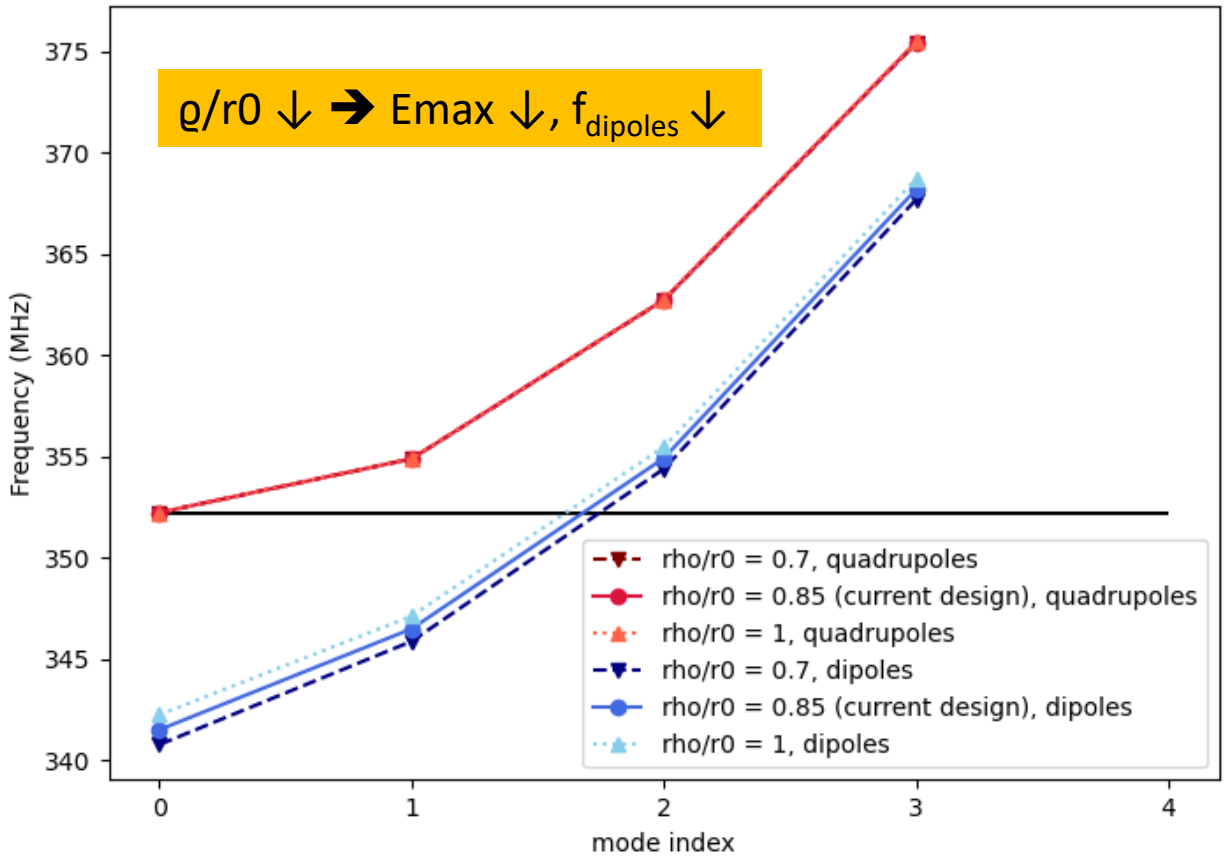
Recap: Mode detuning, Emax with ϱ/r_0 in rfq13

- Improvement is marginal: with $0.7 < \varrho/r_0 < 1.0$ we can move critical dipole HOM by only +/- 0.5 MHz
- ϱ/r_0 has strong effect on maximum surface field! (larger ϱ/r_0, larger field)
- **in the case of 4.5 m long rfq14, reducing ϱ/r_0 moves dipole modes in correct direction** (as opposed to 3.4 m long rfq13)

relative change wrt. ϱ/r_0 in 2D cross-section



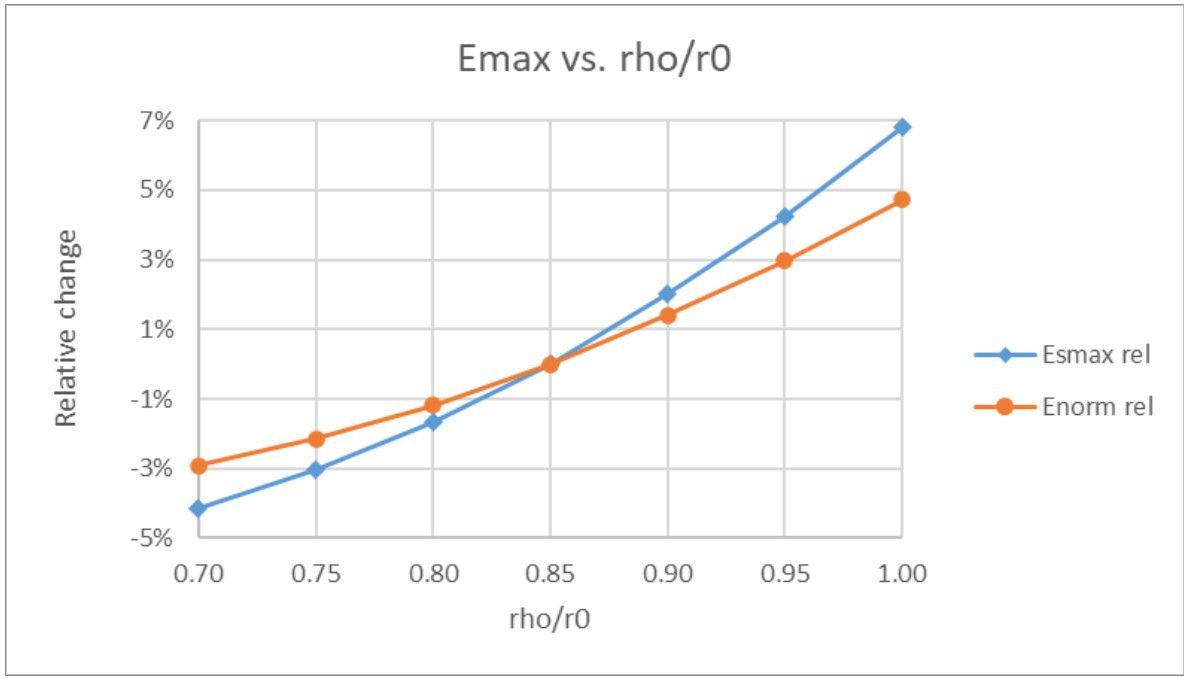
spectrum (TLM estimate) depending on ϱ/r_0



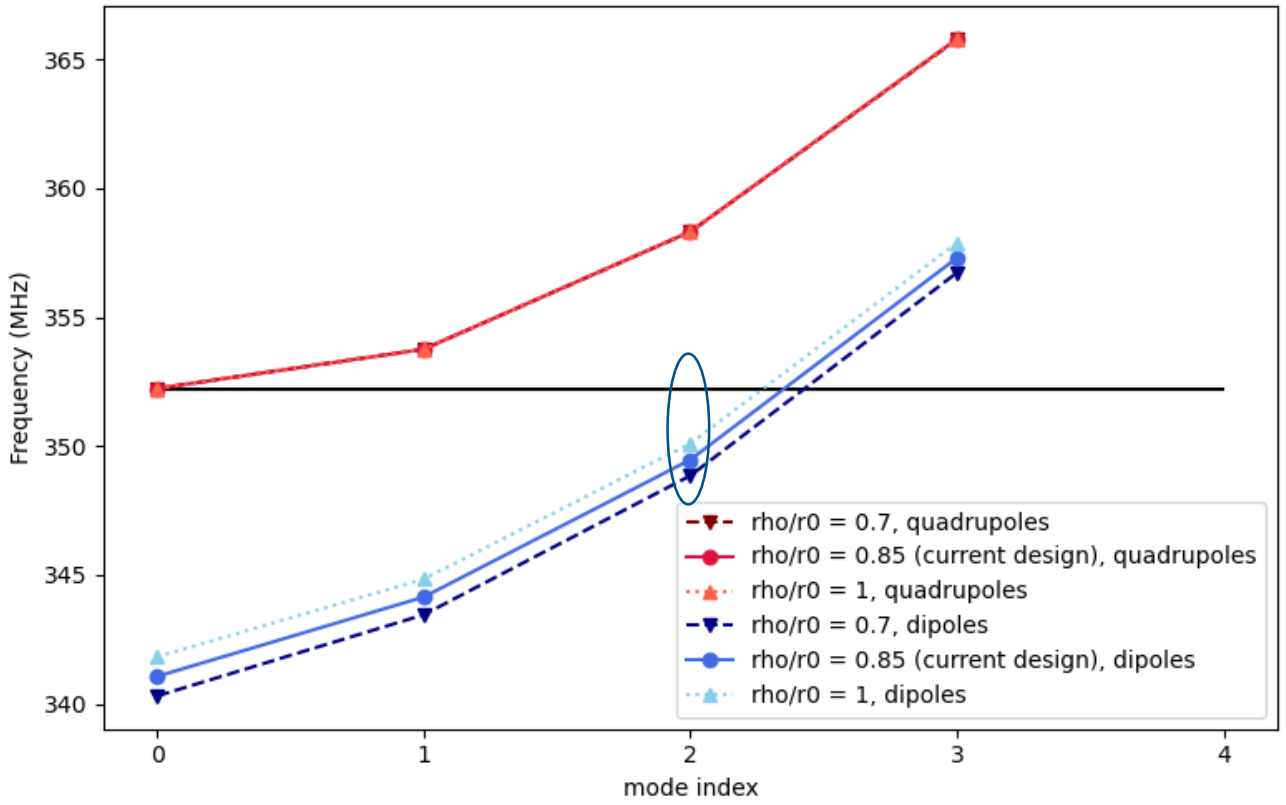
Mode detuning, Emax with ϱ/r_0 in rfq14

- Reducing ϱ/r_0 from 0.85 to 0.7 → proposal „rfq14-2“
  - Emax goes down by 4 %, Enorm by 3 %
  - Spectral margin of dipole increases from 2.8 MHz to 3.4 MHz

relative change wrt. ϱ/r_0 in 2D cross-section

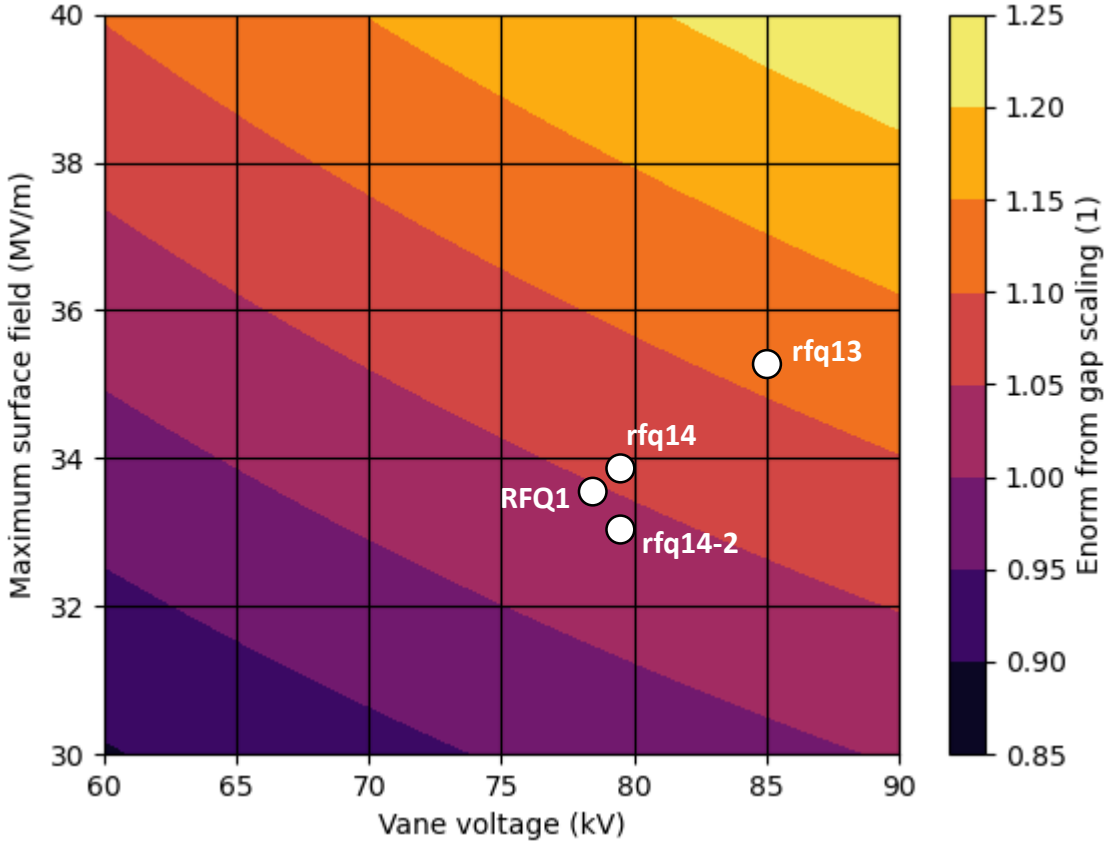


spectrum (TLM estimate) depending on ϱ/r_0



Summary table & outlook

		RFQ1	rfq13	rfq14	rfq14-2 ??
Length	m	3.1	3.4	4.5	4.5
Voltage	kV	78.3	85.0	79.0	79.0
Max. E-field	MV/m	33.6	35.3	33.9	32.5
Gap scaling E_{norm}	1	1.05	1.11	1.06	1.03
ϱ/r_0	1	0.85	0.85	0.85	0.70
$f_{closest\ quadrupole}$	MHz	+3.3	+2.7	+1.5	+1.5
$f_{closest\ dipole}$	MHz	+2.4	+2.5	-2.8	-3.4



Open questions & proposals:

- version „rfq14-2“: same as current 4.5 m RFQ, but with reduced ϱ/r_0:
  lower surface fields, better spectrum, but more multipoles → feasible?
- ignoring the spectrum: what is the shortest RFQ we can design with Emax ≈ 34 MV/m and Enorm ≈ 1.05?
  → might still go for RFQ with dipole detuning rods. Rods are cheaper than 1 m extra RFQ!