



From cylinder to trumpet

Local perturbations in a complete B-flat trumpet

Single and combined changes in peak frequency, impedance magnitude and pressure-node spacing

Research record Release 3 | V0 (no valves engaged)
13 October 2026 | Revision 1.3

The practical goal is to understand where a small bore change can alter a brass instrument's acoustic resonances, and which combinations could later improve selected musical properties. A simple closed-open cylinder provided the starting point. This report transfers that work to a complete trumpet geometry with mouthpiece, leadpipe and bell.

A full V0 FEM series required approximately six hours according to the project run-time recollection. This motivated a checked transfer method: first in the uniform bore, then extended to leadpipe and bell and tested for all seven other valve combinations.

Modes #3 and #8 illustrate enlargements; mode #4 supplies the detailed enlargement/constriction comparison. Joint optimisation across valve combinations is the next stage, not a result claimed here.

Background: [Brassissima on YouTube](#). This PDF builds on the foundations presented in videos 1–3. Watch them as an introduction before reading this document; links are on the final page.

Prepared within the Brassissima project with AI-assisted analysis and documentation. Results are traceable to saved OpenWind data and validation files.

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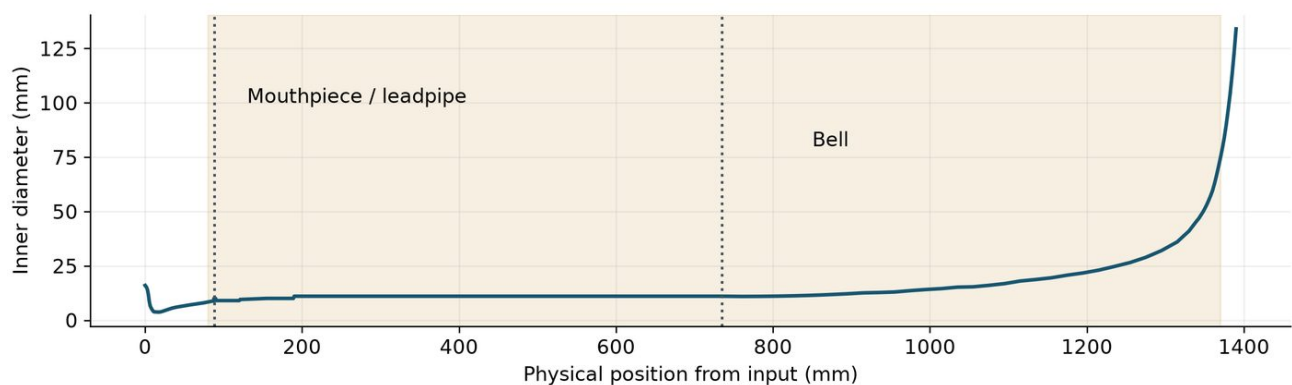
01 What is being investigated?

The research question is: which local change affects which resonances, in which direction, and with which side effects? The physical total length remains unchanged.

Term	Meaning in this report
V0	Complete trumpet, no valves engaged; the valve cluster remains part of the geometry.
Mode #n / peak	The nth ordered input-impedance maximum of the reference; not a played note or an assumed harmonic frequency.
Pressure node	A local minimum of complex-pressure magnitude $ p(x) $ at a specified frequency. With losses, pressure need not reach zero.
Pressure antinode	A local maximum of $ p(x) $, not an instantaneous positive pressure excursion.
Pitch node (PN)	A centre where one specified finite perturbation gives zero peak-frequency change against the unperturbed reference.
XM-PN / XM-IN1 / XM-IN2	Brassissima labels for a selected near-middle pitch node and neighbouring peak-magnitude-change nodes before/after it. Not standard acoustic terminology.
RL / PL / q	Physical tube length / perturbation length / local diameter ratio. q is distinct from resonance quality factor Q.

The historical shared near-middle pitch reference can include a downward offset. It is not identical to a strict zero against the unperturbed spectrum. Here, an actual PN means that strict zero for the specified perturbation.

02 Reference geometry and test conditions



The V0 contour is 1390 mm long: an approximately 88 mm mouthpiece, short partly conical leadpipe, 11 mm cylindrical bore region and flaring bell. The former measured/legacy bell contour was slightly smoothed. This is an adopted reference, not a current measurement of an existing instrument.

Parameter	Value
Reference frequencies	#3: 350.58 Hz #4: 475.86 Hz #8: 937.80 Hz
Temperature / RH / CO ₂	23 °C / 50 % / 0.0004
OpenWind / FEM	0.12.4 / 20 mm element length, order 4
Losses / radiation	Thermoviscous losses on; unflanged radiation; jump masses on; spherical waves off.
Frequency grid	20–2000 Hz; 1/3 Hz
Single-series centres	90–1360 mm, 10 mm step; 128 centres × 2 types = 256 cases.
Local intervals	20 mm; first 80–100 mm, last 1350–1370 mm. Exit diameter unchanged.

The first single-series case may include the final backbore. Detailed multiple examples exclude centres inside the mouthpiece (<88 mm). All positions are measured from physical input x=0.

03 How a perturbation is defined

A constant additive diameter change follows the original contour. It is not a constant q throughout the trumpet. On cones the offset is applied over the complete 20 mm interval, including intermediate geometry points. Entrance and exit jumps are retained.

$$d'(x) = d(x) + \Delta d, \quad x_c - \frac{PL}{2} \leq x \leq x_c + \frac{PL}{2}$$

$$q(x) = \frac{d'(x)}{d(x)} = 1 + \frac{\Delta d}{d(x)}$$

Change	Diameter offset	At 11 mm reference bore
Enlargement	+1.1 mm	12.1 mm; q = 1.1; area ratio = 1.21
Constriction	-1.0 mm	10.0 mm; q = 1/1.1; area ratio = 1/1.21

At smaller reference diameter, the same enlargement gives a larger q; in the bell q approaches 1. Reciprocal diameter ratios apply exactly only where d=11 mm. Elsewhere the fixed +1.1/-1.0 mm offsets are not reciprocal.

These standard values are a practical research convention, with no privileged scientific status. Position, length and diameter offset remain variables for future tests.

The reference already contains cones, gaps and bore changes. Combinations use fixed reference positions; extrema are not relocated after inserting the first change. Overlapping intervals are excluded.

04 What the reported changes mean

$$Z_{\text{in}}(f) = \frac{p(0, f)}{U(0, f)}$$

p is complex acoustic pressure; U is complex volume flow. Input impedance has units $\text{Pa} \cdot \text{s}/\text{m}^3$. Magnitude and phase derive from the same complex spectrum. The unperturbed instrument is always the reference.

$$\Delta c_n = 1200 \log_2 \left(\frac{f'_n}{f_n} \right)$$

$$\Delta M_n = 100 \left[\frac{|Z'(f'_n)|}{|Z(f_n)|} - 1 \right]$$

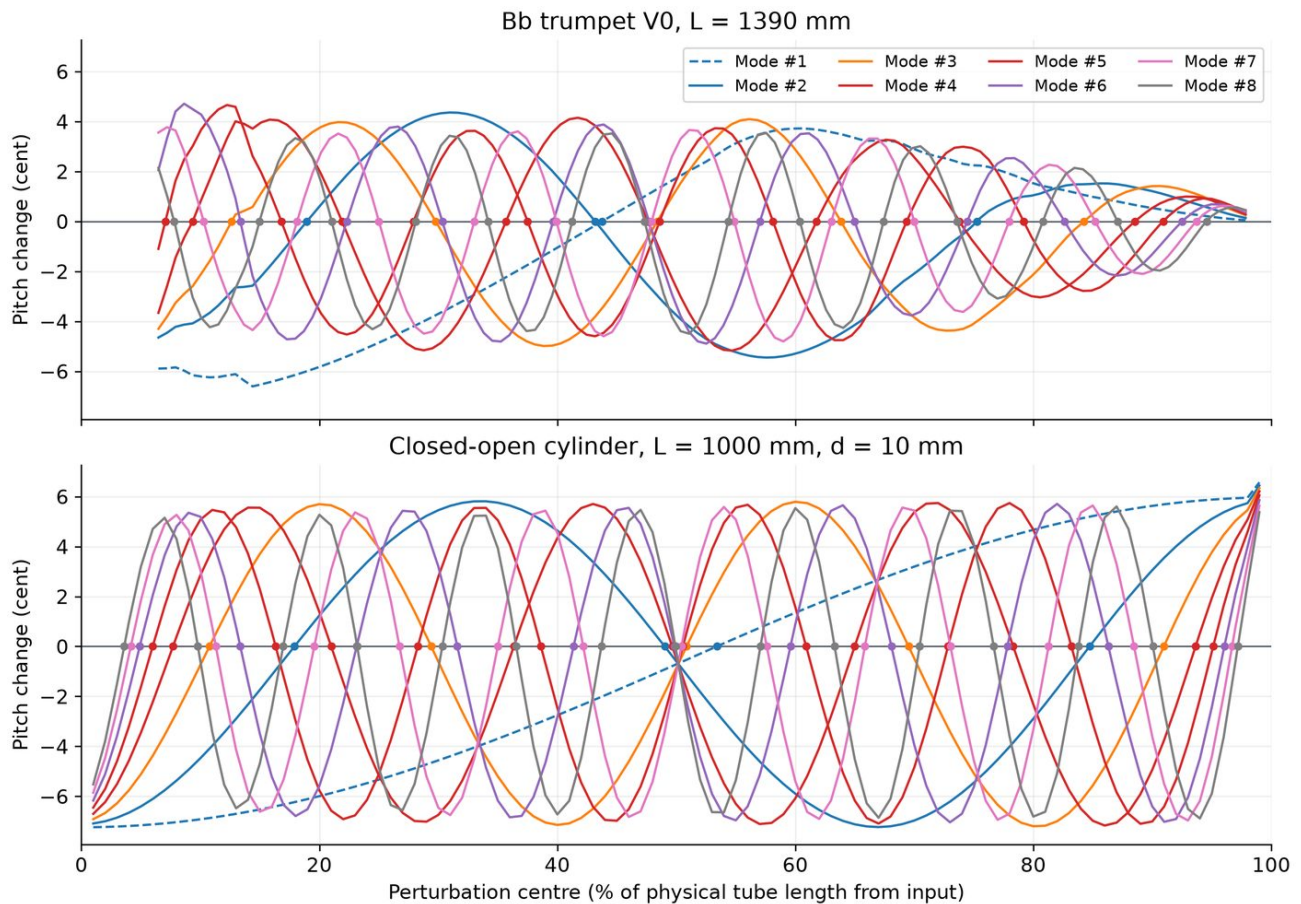
$$r_{M,n} = 1 + \frac{\Delta M_n}{100}; \quad \Delta L_n = 20 \log_{10} (r_{M,n}) \text{ dB}$$

f_n and f'_n are tracked reference and perturbed peak frequencies. Magnitude is compared at each spectrum's own peak. Three-point quadratic refinement is used on the 1/3 Hz grid; tracking remains within windows around reference peaks.

Pressure fields are normalised to the same input volume flow. Higher $|Z_{\text{in}}|$ then means higher input-pressure magnitude. Without this normalisation, “pressure increases at the input” is ambiguous.

Peak magnitude is not a direct score of playing response or musical quality. Minima, phase, impulse response and linewidth remain important additional observables, but are not newly analysed here.

05 Modes #1–#8: cylinder and trumpet pitch potential

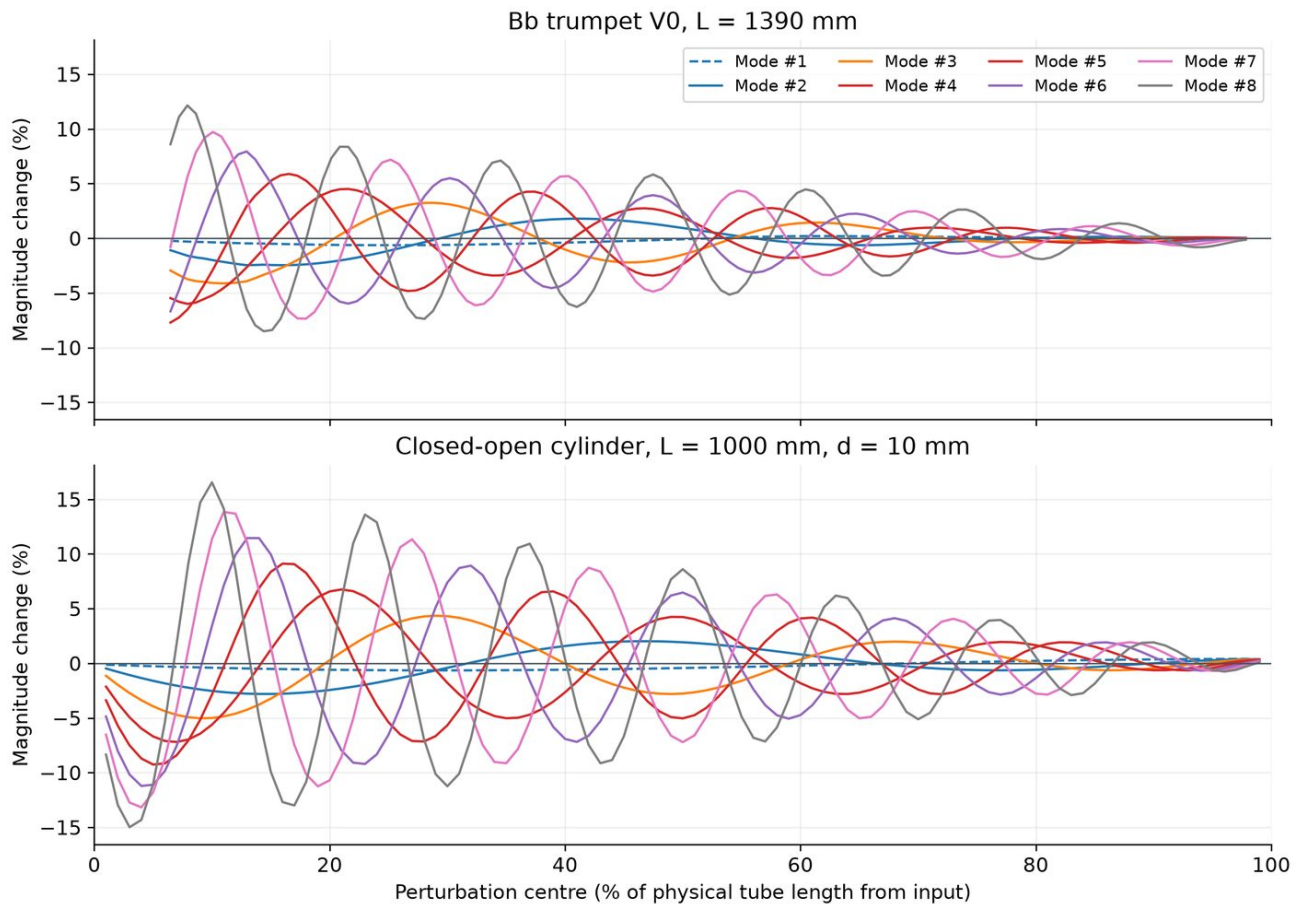


Top: complete trumpet V0. Bottom: closed-open cylinder. All curves are single enlargements; dots mark zero crossings found by linear interpolation of the sampled pitch curve. These are actual zeros relative to each unperturbed reference, not the offset-centred historical shared node.

The cylinder modes have approximately comparable pitch potential: observed minima range from -7.24 to -6.89 cent, maxima from $+5.60$ to $+6.57$ cent. They are not exactly equal. In the trumpet, both potential and physical node locations depend more strongly on mode and local contour; mode #1 is retained here for comparison only.

Both tests use $PL=20$ mm, 23°C , 50% RH, losses and unflanged radiation. Cylinder: $d=10$ mm, $q=1.1$ throughout, $\Delta d=+1$ mm, $PL/RL=2\%$. Trumpet: $\Delta d=+1.1$ mm, $q=1.1$ only at $d=11$ mm, $PL/RL\approx 1.44\%$. Mode numbers do not represent equal frequencies across geometries; the comparison is descriptive, not an isolated bell-effect experiment.

06 Modes #1–#8: cylinder and trumpet magnitude potential



Top: trumpet; bottom: cylinder, with the same scales. Unlike pitch potential, cylinder magnitude potential already depends strongly on mode. In both cases, changes oscillate with position and generally weaken towards the open end. The trumpet modifies amplitude, asymmetry and the spatial placement of extrema.

Examples of observed single-change magnitude ranges: mode #3, cylinder $-5.03\ldots+4.35\%$, trumpet $-4.12\ldots+3.24\%$; mode #8, cylinder $-14.98\ldots+16.55\%$, trumpet $-8.50\ldots+12.14\%$. These are extrema on the available position grid, not mathematically proven continuous maxima.

The cylinder is sampled at 1–99% physical length; the trumpet at 90–1360 mm (about 6.47–97.84%). A near-input trumpet maximum can therefore lie outside the plotted domain. Geometry, frequencies, local q and relative perturbation length all contribute to these differences.

07 From hours of FEM to a checked transfer method

The initial approach computed a complete OpenWind spectrum separately for every perturbation position and both change types. The V0 run took approximately six hours according to the project recollection; this is not a fresh timing benchmark. Repeating such a full series for every valve combination would require substantial additional computation.

Stored series	Verified scope
Closed-open cylinder	199 cases: one reference plus 99 enlargements and 99 constrictions.
Trumpet V0	276 perturbations (138 centres × 2 types), plus the separate unperturbed reference.
Extended V0 selection	256 of those perturbations: 128 centres at 90–1360 mm, both types.

Development in three steps. First, the reference-based method was checked in the uniform 11 mm bore. Second, the local-section transfer was extended to non-cylindrical leadpipe and bell contours, including losses and junction masses. Third, each further valve combination was calculated with its own unperturbed complex reference and corresponding geometry; V0 curves were not merely shifted.

For V2, V1, V3, V12, V23, V13 and V123, a complete moving-perturbation FEM series is no longer required. After the shared upstream transfer has been established, each combination needs its reference spectrum and known geometry. Local changes are then computed mathematically; OpenWind FEM supplies independent spot checks.

Already completed: 2232 predictions across the seven combinations; eight FEM checks per combination (56 total), covering 504 peak comparisons for modes #2–#10. All chosen thresholds were met. Pure prediction time per combination was about 42–50 seconds, excluding reference preparation and FEM checks. This is a major time/computation advantage, not a hardware-independent speed-up factor.

This transfers the simulation method to the other tube lengths. Combining their musical targets and shared physical paths in one optimisation remains the next research task.

08 The complex reference-based transfer model

The faster calculation uses known reference geometry and its complex OpenWind spectrum. It replaces a section mathematically instead of repeating a full FEM sweep for each moving perturbation. It is not an empirical pitch formula and does not uniquely recover unknown geometry from impedance alone.

$$p_{\text{in}} = Ap_{\text{out}} + BU_{\text{out}}; \quad U_{\text{in}} = Cp_{\text{out}} + DU_{\text{out}}$$

$$F_T(Z) = \frac{AZ+B}{CZ+D}$$

$$F_T^{-1}(Z) = \frac{B-DZ}{CZ-A}$$

For physical p and U , A and D are dimensionless, B has impedance units and C inverse-impedance units. All depend on frequency and may be complex. Z_{load} is a section's acoustic termination, not a separate amplitude coefficient.

$$Z_{\text{down}} = F_{T_{\text{local}}}^{-1}(F_{T_{\text{up}}}^{-1}(Z_{\text{ref}}))$$

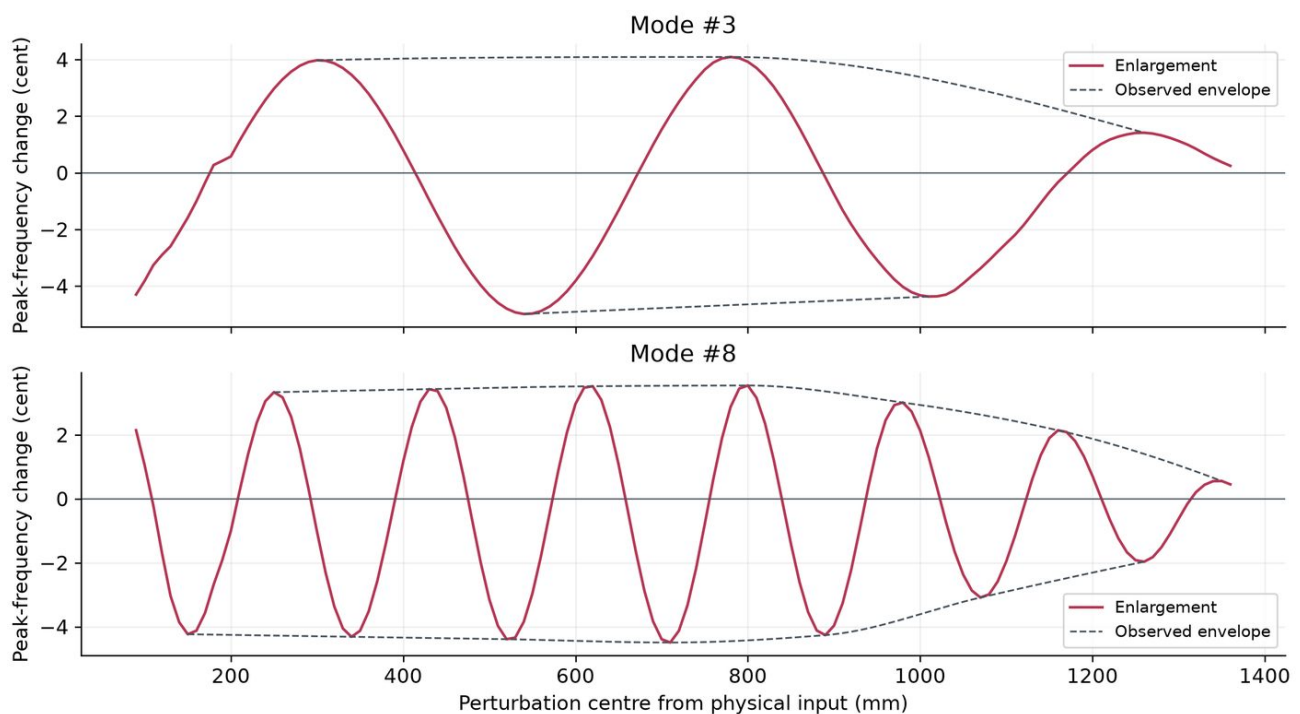
$$Z'_{\text{in}} = F_{T_{\text{up}}}(F_{T'_{\text{local}}}(Z_{\text{down}}))$$

Upstream transfer is anchored at 190 mm. Mouthpiece/leadpipe transfer was determined from three computed terminations: perfectly open, closed and unflanged. Known contour sections are propagated using OpenWind-based lossy matrices; cones are subdivided and jump masses included.

The recovered reference matrix is defined up to a common scale, which cancels in F_T . Pressure-field amplitudes in this report are calculated separately with FEM.

Several changes are combined in physical order, using changed and unchanged sections or an algebraically equivalent reference operator. Joint results are not obtained by adding cent/percentage changes or multiplying isolated group factors.

09 Single perturbations: peak frequency



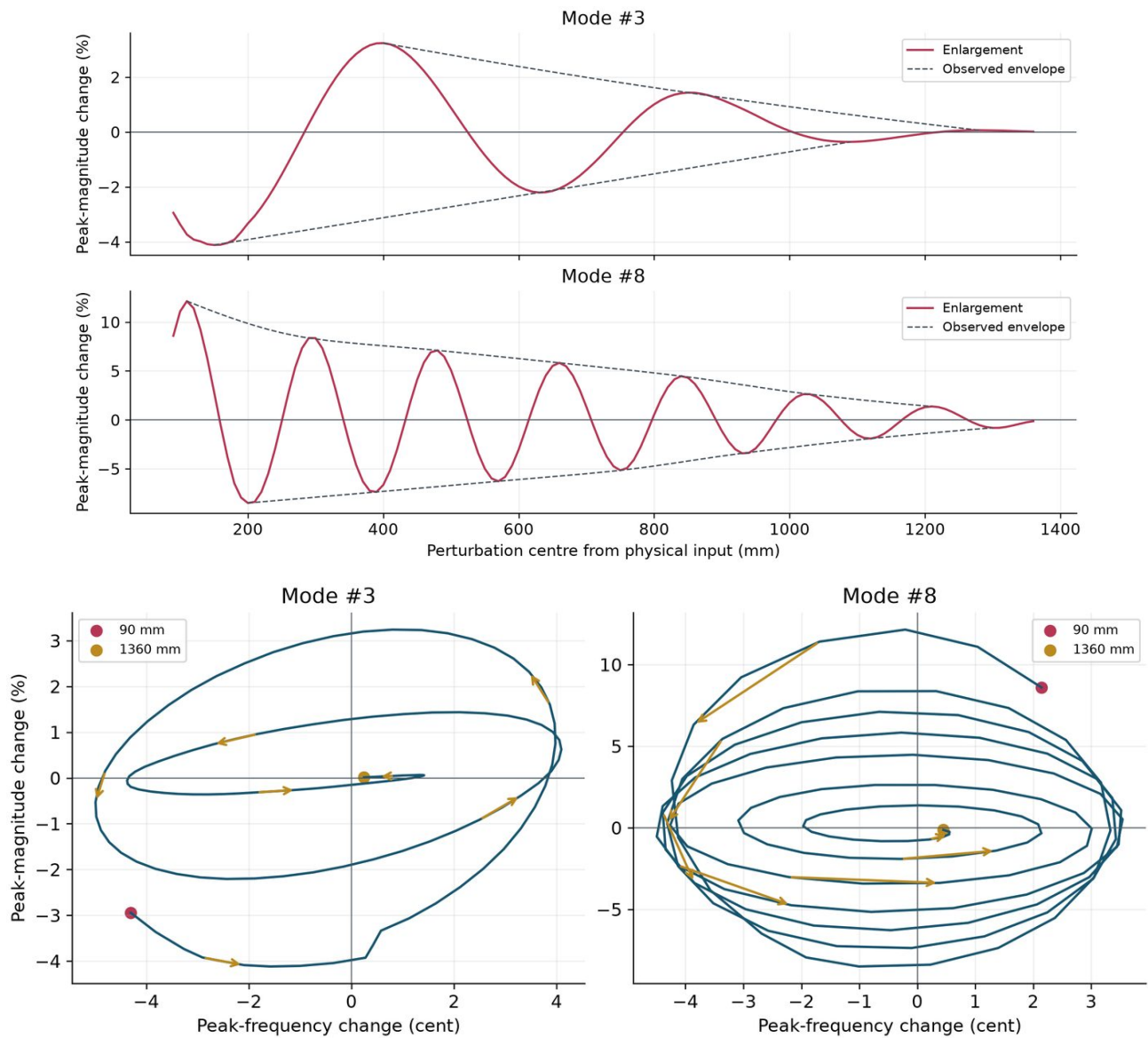
Each curve follows one mode while the 20 mm change moves from 90 to 1360 mm. These V0 single cases come from stored complete FEM simulations. Dashed envelopes use shape-preserving interpolation between observed positive/negative extrema, without extrapolation. Alternating pitch directions appear rather than a simple monotonic trend along the trumpet.

A larger local q does not guarantee a larger signed pitch change at one position. Response also depends on pressure/flow distribution and the integrated effect across the finite interval. A weak change can occur near a pitch node despite substantial neighbouring extrema.

Positive and negative extrema can be connected into envelopes of observed potential. Such envelopes interpolate sampled extrema; a 10 mm grid does not prove the exact continuous maximum.

Quarter-wavelength rules from the cylinder provide intuition, not a universal trumpet amplitude formula.

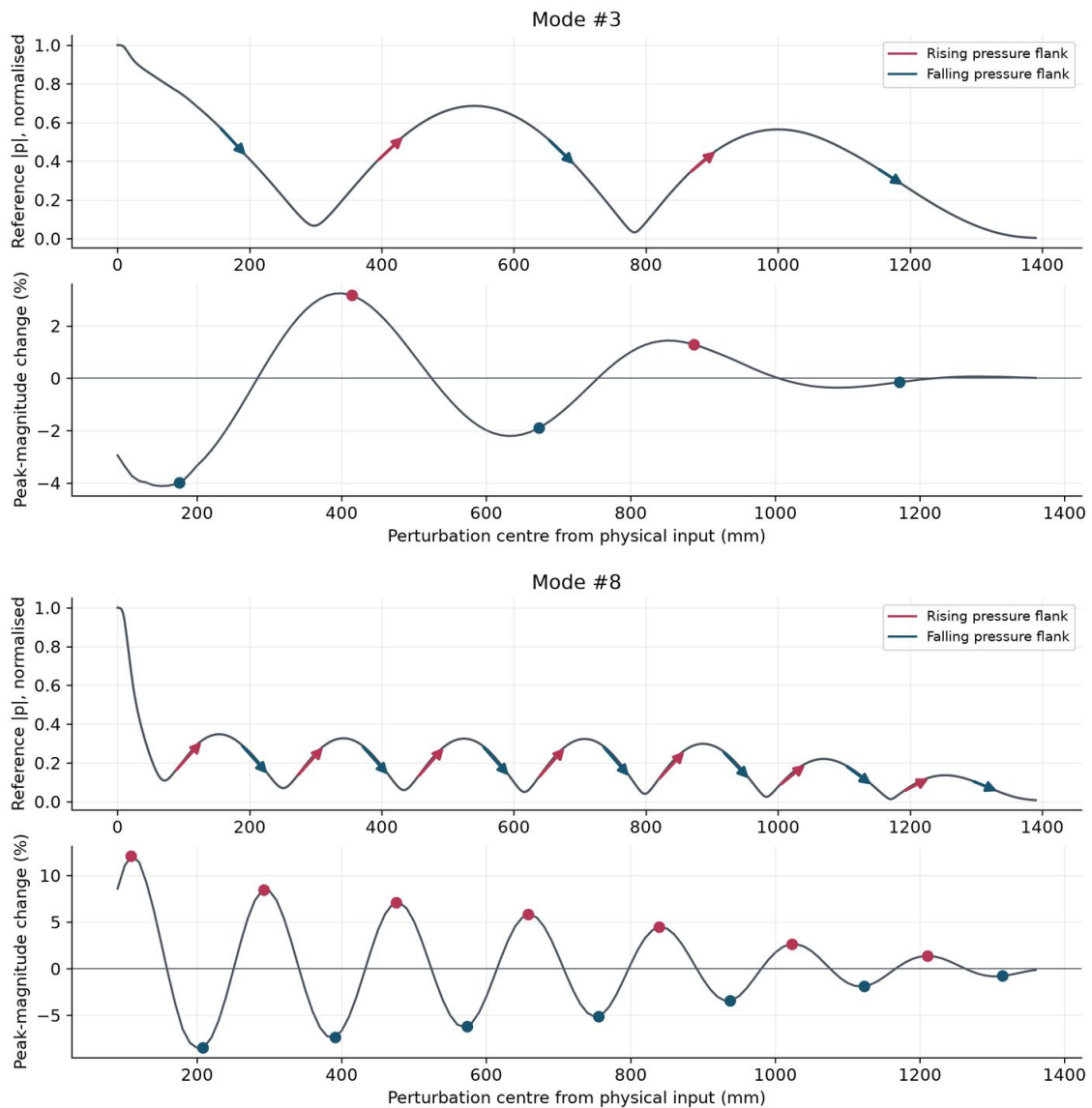
10 Single perturbations: magnitude and spirals



The lower plots combine enlargement pitch and magnitude changes. Arrows follow increasing centre position. Winding paths arise from oscillating pitch and position-dependent magnitude potential; ideal spirals are not assumed.

In these cases magnitude effects weaken towards the open end. Mouthpiece, leadpipe and bell alter acoustic positions; 50% physical length is therefore not a universal trumpet pitch-node prescription.

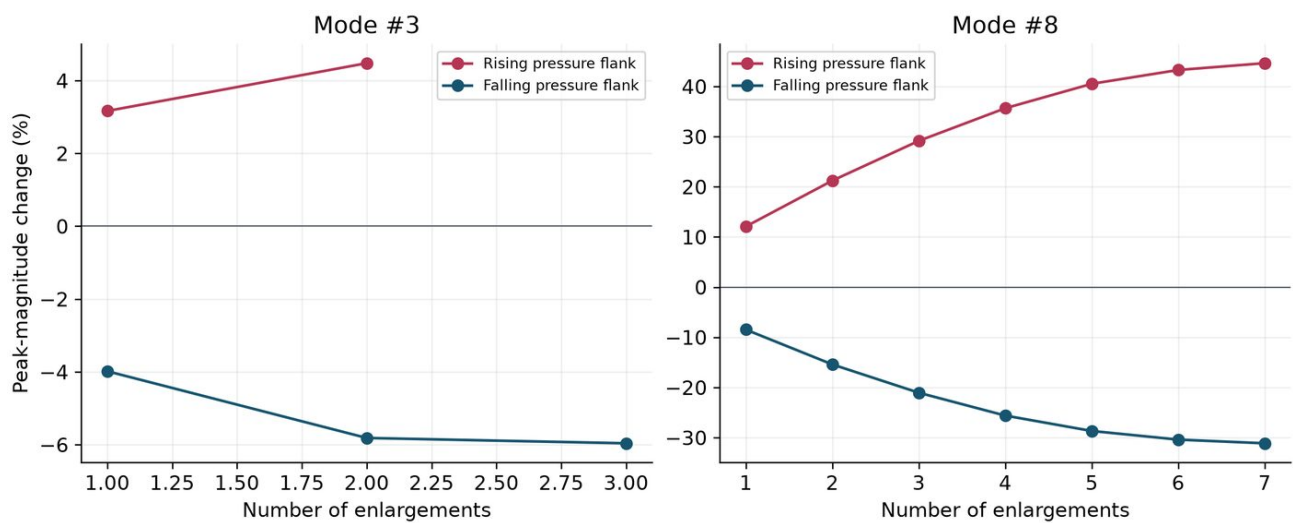
11 Pitch nodes: the pressure flank matters



Top in each pair: reference $|p(x)|$ at the mode's peak frequency. Red/blue arrows indicate spatial flank direction around the actual single-enlargement centre, using the same centre coordinates as the highlighted magnitude points below; they are not pressure-node markers or generic flank midpoints. Bottom: full magnitude-change curve of single enlargements, with actual PNs highlighted. Rising/falling describes spatial change from input to bell, not time or phase.

Rising flank: magnitude increases. Falling flank: magnitude decreases. This sign pattern occurred at all 92 tested single enlargement PNs outside the mouthpiece across modes #2–#10. Only modes #3 and #8 are shown.

12 Several enlargements: selected groups



Mode	PN flank group	Count	Pitch (cent)	Magnitude (%)
#3	Rising	2	-0.003	+4.48
#3	Falling	3	-0.006	-5.96
#3	Both groups together	5	+0.010	-1.66
#8	Rising	7	+0.126	+44.63
#8	Falling	7	-0.036	-31.14
#8	Both groups together	14	-0.017	+8.17

The curves add same-flank centres from input to bell. Sites with the same magnitude direction reinforce the effect while the selected mode's pitch remains almost unchanged. These are fixed reference locations, not a re-optimised sequence.

Mode #8 gives separate factors 1.446 and 0.689: about +3.21 and -3.24 dB despite unequal percentages. Multiplying them would give -0.40%, but the actual joint 14-site geometry gives +8.17%. Near-reciprocal group factors are not a rule for combining changes.

13 Mode #4: constrictions reverse the directions

At the same reference extrema, constrictions reverse single-change pitch and local-spacing directions. Their diameter offset is -1.0 mm over 20 mm. All one-, two- and three-site combinations within the three antinodes and within the three nodes were examined.

Single change	Enlargement	Constriction
At an antinode	Pitch down; enclosing interval shorter; other sections longer.	Pitch up; enclosing interval longer; other sections shorter.

At a pressure node	Pitch up; both adjacent intervals longer; distant sections shorter.	Pitch down; both adjacent intervals shorter; distant sections longer.
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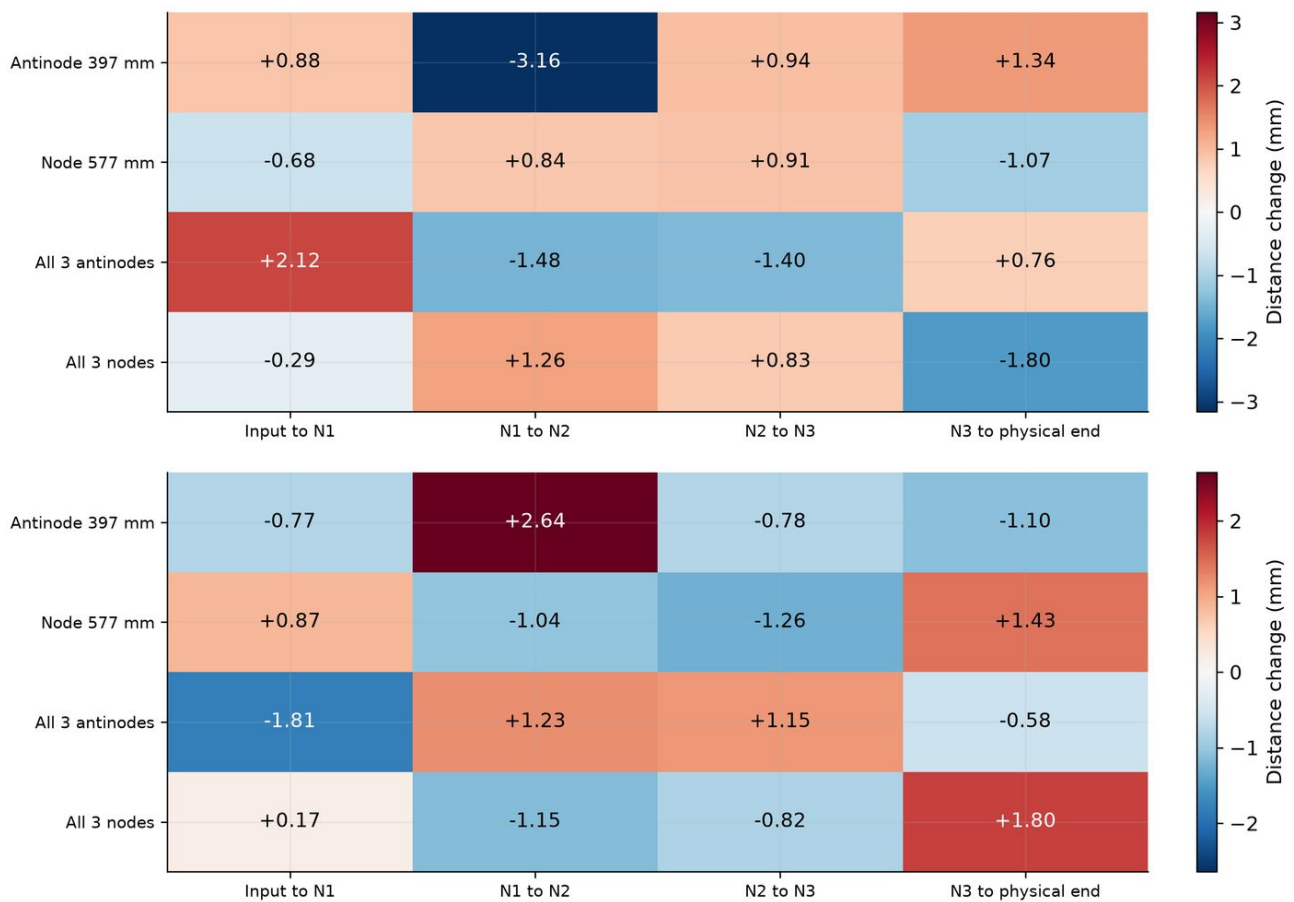
Group	Enl. cent	Constr. cent	Enl. Z %	Constr. Z %
All 3 antinodes	-13	+11	-1.00	+0.99

All 3 nodes	+11	-15	+1.91	-2.60
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Directions agree with the local/global counter-pattern; strengths are not exact mirror images. Diameter offsets, non-reciprocal ratios outside the 11 mm bore, losses, jumps and finite geometry remain in the model. This comparison alone does not attribute asymmetry to one cause.

An antinode/node selection concerns one mode. The same physical change also affects others; no protected musical range follows from this result alone.

14 The dam effect: local and global redistribution



Upper chart: enlargements. Lower chart: constrictions. Entries are distance changes in millimetres. Reference inner nodes: 218.07, 576.53, 949.58 mm. The last column ends at the physical bell rim, not an assumed exact pressure zero.

One enlargement at the 397 mm antinode shortens its enclosing interval by 3.16 mm while other sections lengthen. The corresponding constriction lengthens it by 2.64 mm. At the middle pressure node, enlargement lengthens both neighbours; constriction shortens them.

With several changes, each interval shows the net balance. All three antinode enlargements deepen pitch, yet the final, also perturbed section becomes 0.76 mm longer. The global frequency shift can outweigh a local effect. The dam effect is a descriptive analogy, not a new conservation law or complete pitch formula.

15 Mode #4: actual pitch nodes and magnitude extrema

An enlargement PN is not automatically a constriction PN. Centres shift about 9–24 mm here. At the old enlargement nodes, both constriction groups also give a small downward pitch change. Re-locating actual zeros separates this offset from the magnitude effect.

Flank	Enlargement PN (mm)	Constriction PN (mm)
Falling	130.1	106.4
Rising	304.5	318.3
Falling	496.0	482.4
Rising	661.8	675.3
Falling	858.8	843.9
Rising	1025.7	1034.6
Falling	1230.6	1217.4

Actual PN group	Count	Enlargement Z %	Constriction Z %
Rising	3	+8.02	-7.82
Falling	4	-10.04	+12.47

All 127 non-empty subsets of seven centres were tested for each type at its own nodes. Enlargement extrema: +8.02% with three rising sites, -10.04% with four falling sites. Constriction extrema: +12.47% with four falling sites, -7.82% with three rising sites.

No same-direction site was omitted. These are exhaustive extrema within seven selected nodes, not global optima over arbitrary positions, lengths or strengths. The selected full flank groups keep mode #4 within 0.03 cent of its reference.

16 What is verified - and what remains open

Parentheses express pitch error as a percentage of frequency, and magnitude error as a percentage of the reference peak. The latter equals the numerical value in percentage points (pp) of ΔM ; it is not relative to ΔM itself.

Independent FEM check set	Cases	Max pitch error (cent)	Max magnitude error (pp)
Earlier combined-enlargement tests	18	1.45e-05 (0.0000008368 % f)	5.90e-05 (0.00005896 % Zref)
Same-flank enlargement groups #3/#8	4	6.37e-06 (0.0000003679 % f)	4.66e-05 (0.00004661 % Zref)
Actual constriction PN groups #4	2	3.70e-06 (0.0000002134 % f)	1.54e-05 (0.00001538 % Zref)

The first set includes earlier mouthpiece sites; not all 18 cases are mouthpiece-excluded examples shown here. Constriction checks use two complete changed geometries in a dense FEM frequency window around mode #4. Node-spacing comparisons use direct FEM fields at each case's tracked peak.

Numerical agreement validates calculation within a model; it is not experimental accuracy. Both methods share assumptions about geometry, losses, radiation and junctions. These multiple-change results have not yet been validated by new calibrated measurements on a physical trumpet.

Sign patterns and spacing directions are supported for selected cases, not universal laws for all geometries and strengths. Almost unchanged pitch does not require stationary pressure nodes: mode #4 PN groups retain small spatial shifts.

The range excludes the mouthpiece entrance and final bell rim. Known geometry is required; broadband phase/IR accuracy and unknown-geometry inversion are separate issues. Linewidth and quality factor Q are not assessed here.

17 Next stage: optimisation of the shared instrument

The results provide candidate selection: pressure extrema for strong pitch effects; PN flanks for predominantly magnitude effects; then joint complex calculation of all effects on relevant modes. These tests diagnose behaviour, not an already improved instrument.

1. Define musical goals. Use established Excel note/valve assignments, equal-temperament deviations and weights. Separate pitch targets from magnitude limits; restrict current optimisation interest to peaks below 1500 Hz.
2. Link physical paths. A shared bell modification must affect every relevant valve combination. The same physical location may have different path coordinates before, inside and after the cluster. Use saved Vstart/Vstop and valve-path assignments, not a uniform V0 shift everywhere.
3. Search jointly, then verify. Explore several small changes, calculate mode/valve side effects, apply manufacturing limits to promising candidates and verify complete geometries with FEM and later calibrated measurements. Prioritise V0, V2, V1 and V3 by musical importance.

Project and background

This PDF builds on the foundations presented in the Brassissima videos. Videos 1–3 should therefore be watched as an introduction before reading this document.

[Brassissima project](#)

[Brassissima YouTube channel](#)

[Video 1: acoustic foundations](#)

[Video 2: cylinder perturbations](#)

[Video 3: trumpet and transfer model](#)

Data record: V0 reference geometry/spectrum; extended single series; multiple-enlargement results and FEM checks; pitch-flank groups; mode #4 spacing and constriction results. `source_manifest.json` lists source paths, sizes and SHA-256 hashes. Saved data take precedence over rounded display values.