Mapping of Stagnation Conditions in Reflected Shock Tunnels.

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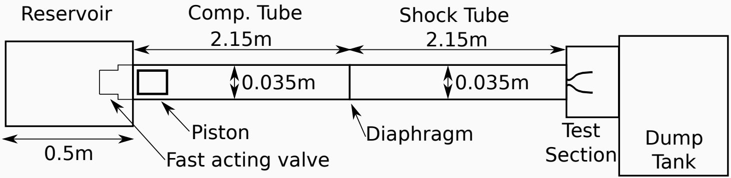
Reflected Shock Tunnels

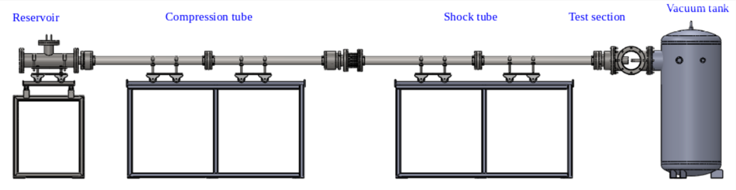
Reflected Shock Tunnels

- High enthalpy
- High stagnation pressures

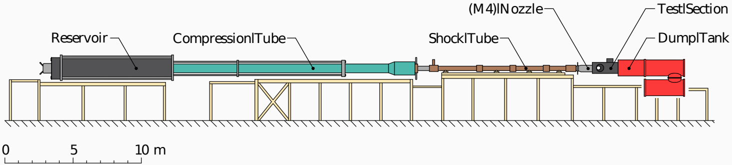


RST sketch.

Reflected Shock Tunnels



TU-RST.



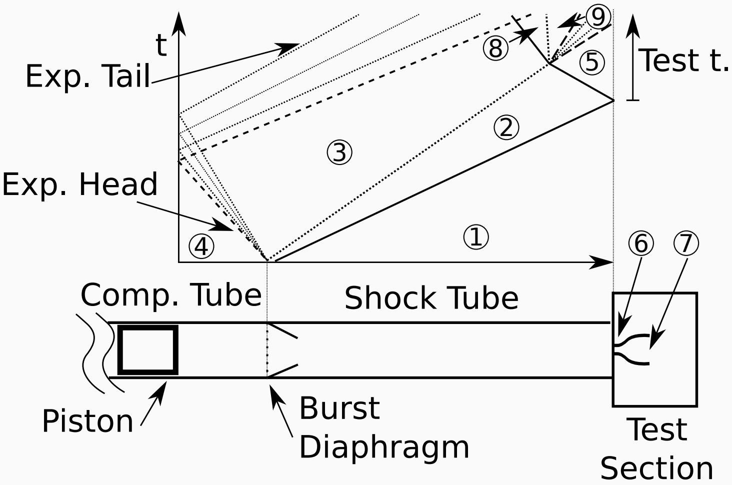
T4 reflected shock tunnel, from Doherty, L.J. PhD thesis.

- Tokai University RST (TU-RST)
- T4 at University of Queensland

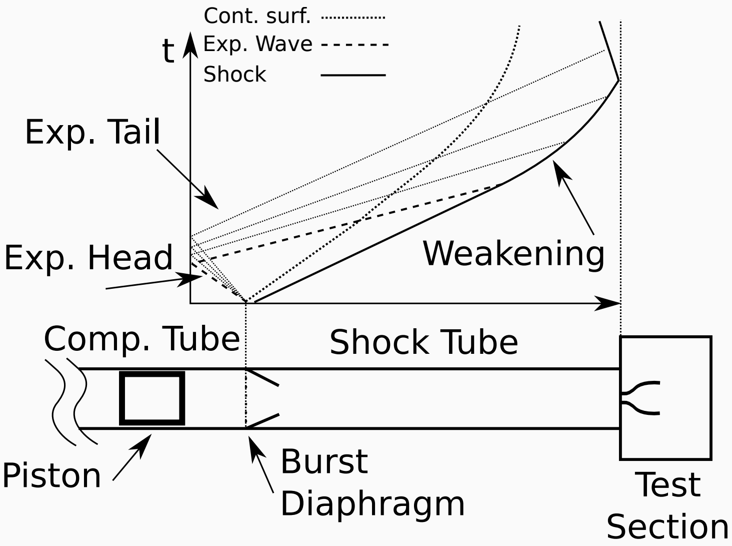
RST at Tokai University and T4 at UQ.

Facility	Res. Volume	CT length	ST length	CT ⌀	ST ⌀	Piston mass
TU-RST	10.23×10^{-3} m^3	2.15 m	2.15 m	0.035 m	0.035 m	0.319 kg
T4	0.675 m^3	26.0 m	10.0 m	0.229 m	0.076 m	87.0 kg

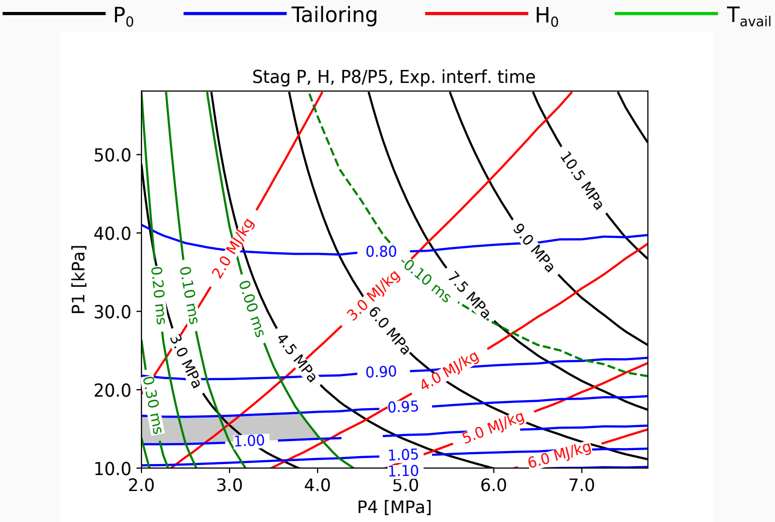
Shock diagrams


t
Exp. Tail
Exp. Head
④
③
②
①
⑧
⑨
⑤
Test t.
⑥ ⑦
Comp. Tube
Shock Tube
Piston
Burst
Diaphragm
Test
Section

Ideal case.

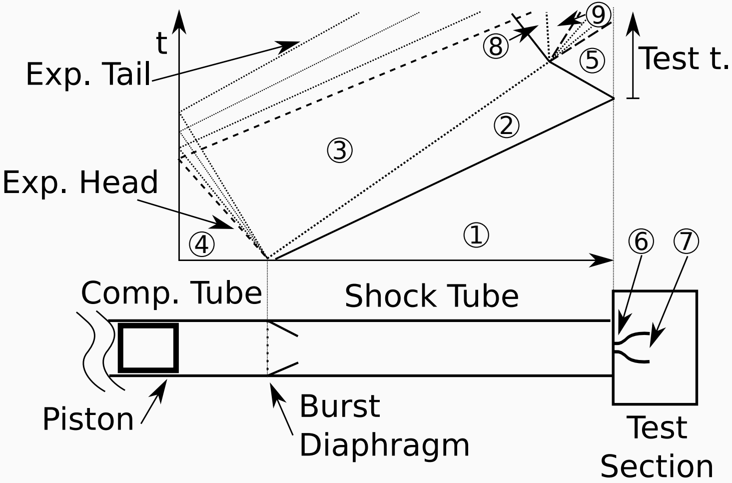


Case with interference.



Map of stagnation conditions.

Calculation of States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Ideal case.

Use of ESTCj and related libraries coupled with CEA.

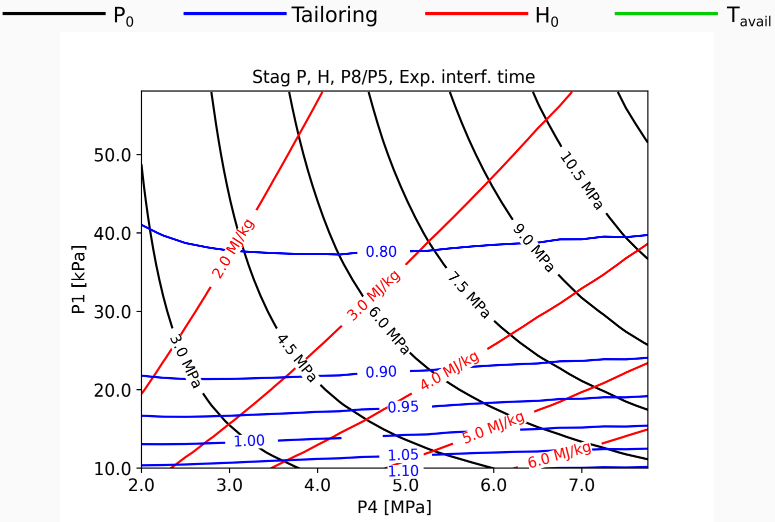
Initial guess for P2:

$$\frac{P_4}{P_1} = \frac{P_2}{P_1}\left(1 - \frac{(\gamma_4 - 1)\,(c_1/c_4)\,(P_2/P_1 - 1)}{\sqrt{2\gamma_1\,[2\gamma_1 + (\gamma_1 + 1)\,(P_2/P_1 - 1)]}}\right)^{\frac{-2\gamma_4}{\gamma_4 - 1}} \tag{1}$$

$$V_S = c_1\left[\frac{\gamma_1 + 1}{2\gamma_1}\left(\frac{P_2}{P_1} - 1\right) + 1\right]^{\frac{1}{2}} \tag{2}$$

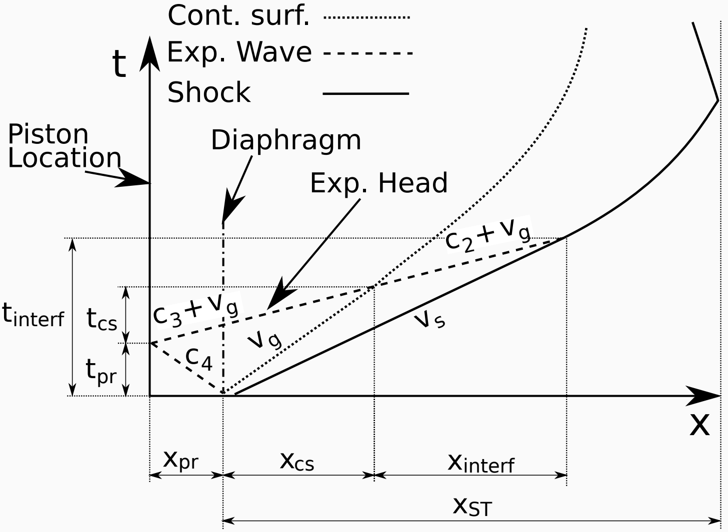
With expansion from P_4 to P_3, with $P_3 = P_2$ get condition 3.
$V_2 - V_3$ = error function to solve iteratively.

Reference Map

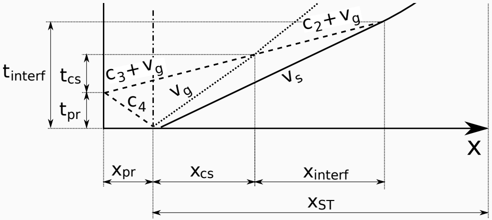


Map of stagnation conditions.

Calculation of Interference



Interference time measurement.



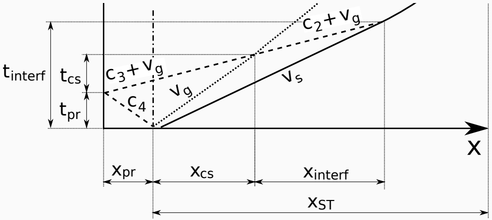
Interference time measurement.

$$t_{pr} = \frac{X_{pr}}{c_4} \tag{3}$$

$$\frac{X_{cs} + X_{pr}}{c_3 + V_g} + \frac{X_{pr}}{c_4} = \frac{X_{cs}}{V_g} \tag{4}$$

$$X_{cs} = \left(\frac{X_{pr}}{c_3 + V_g} + t_{pr} \right) \frac{1}{\frac{1}{V_g} - \frac{1}{c_3 + V_g}} \tag{5}$$

Calculation of interference time



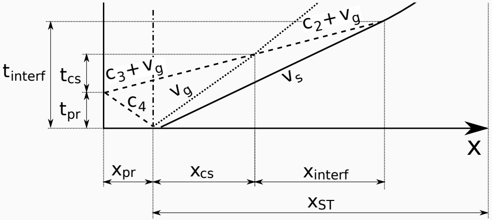
Interference time measurement.

$$t_{cs} = \frac{X_{cs}}{V_g} - t_{pr} \tag{6}$$

$$\frac{X_{cs} + X_{pr}}{c_3 + V_g} + \frac{X_{pr}}{c_4} + \frac{X_{interf}}{c_2 + V_g} = \frac{X_{cs} + X_{interf}}{V_s} \tag{7}$$

$$X_{interf} = \left(\frac{X_{cs}}{V_s} - \left(\frac{X_{cs} + X_{pr}}{c_3 + V_g} + \frac{X_{pr}}{c_4} \right) \right) \frac{1}{\frac{1}{c_2 + V_g} - \frac{1}{V_s}} \tag{8}$$

Calculation of interference time



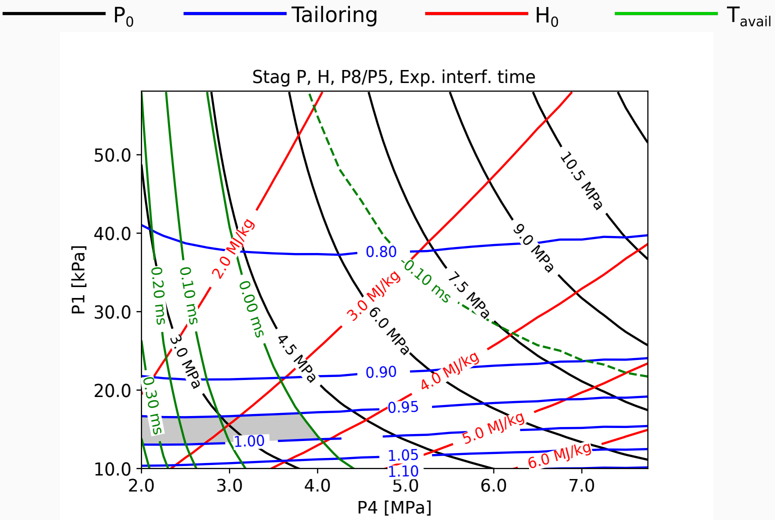
Interference time measurement.

$$t_{interf} = \frac{X_{cs} + X_{interf}}{Vs} \tag{9}$$

$$t_{stag} = \frac{X_{ST}}{Vs} \tag{10}$$

$$t_{avail} = t_{interf} - t_{stag} \tag{11}$$

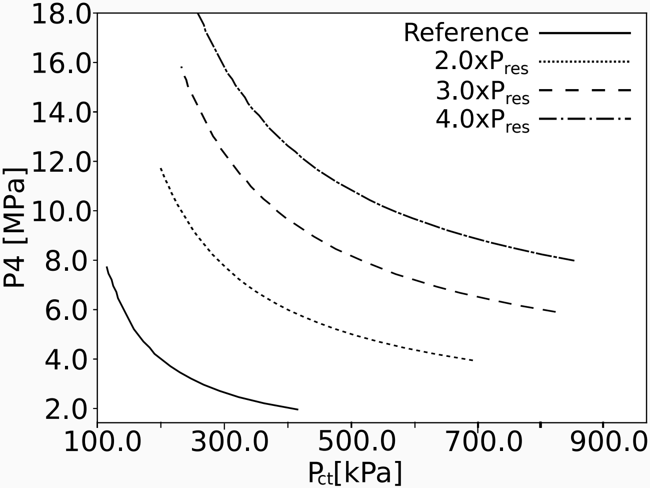
Maps



Map of stagnation conditions.

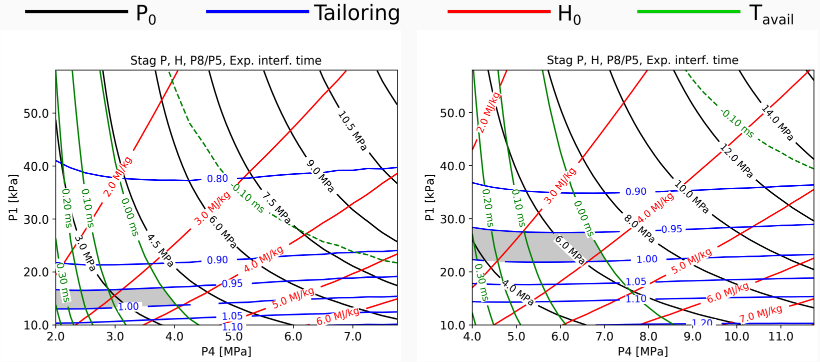
Effect of Reservoir Pressure

Variation of Reservoir Pressure



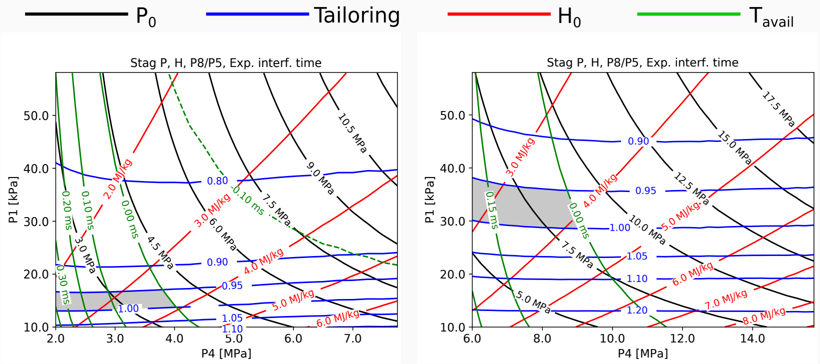
Curves of Rupture Pressure.

Effect of Max Res. P



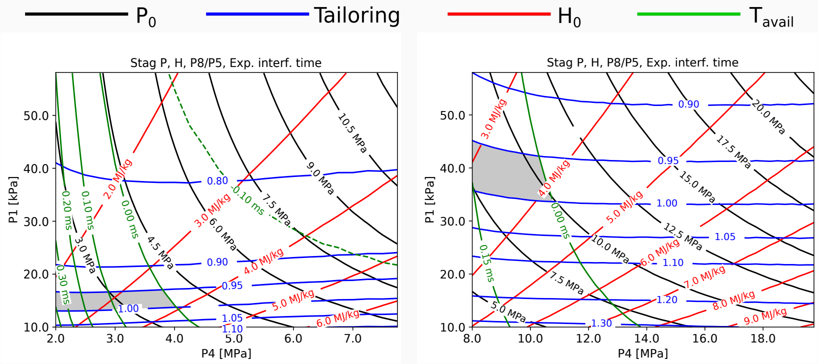
1x and 2x Reservoir P.

Effect of Max Res. P



1x and 3x Reservoir P.

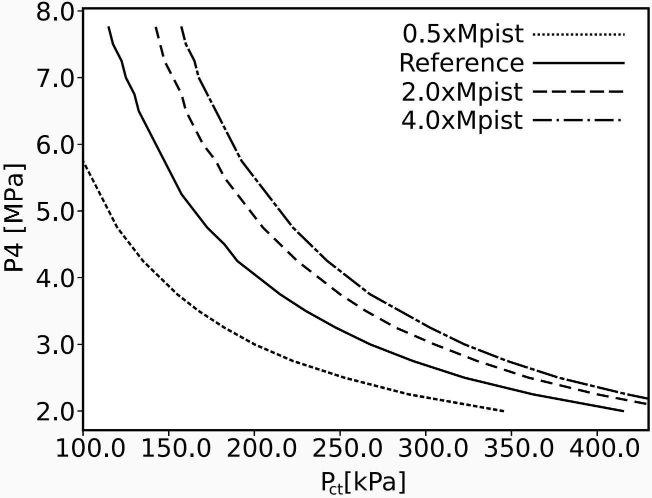
Effect of Max Res. P



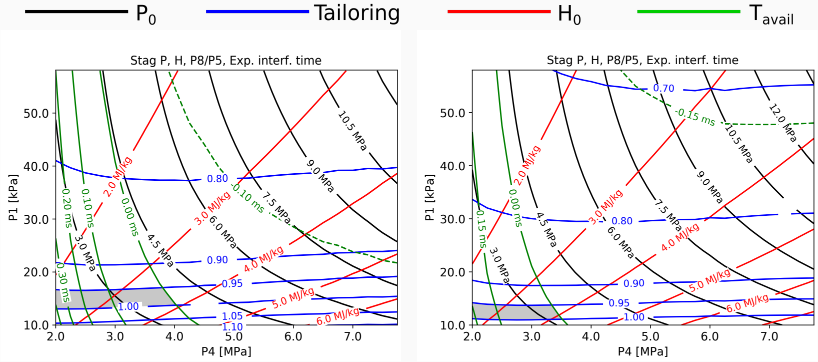
1x and 4x Reservoir P.

Effect of Piston Mass

Effect of Piston Mass

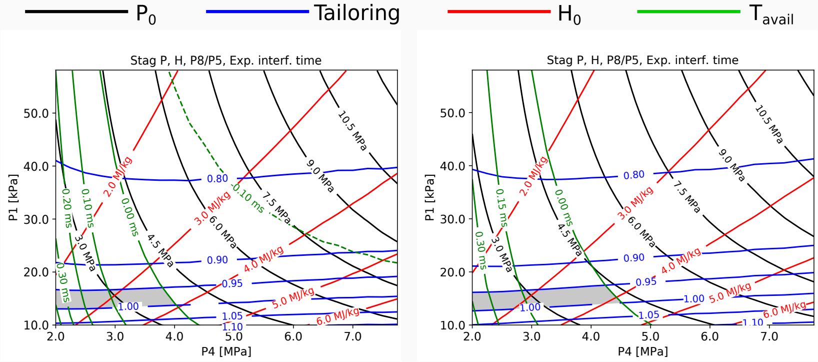


Curves of Rupture Pressure.



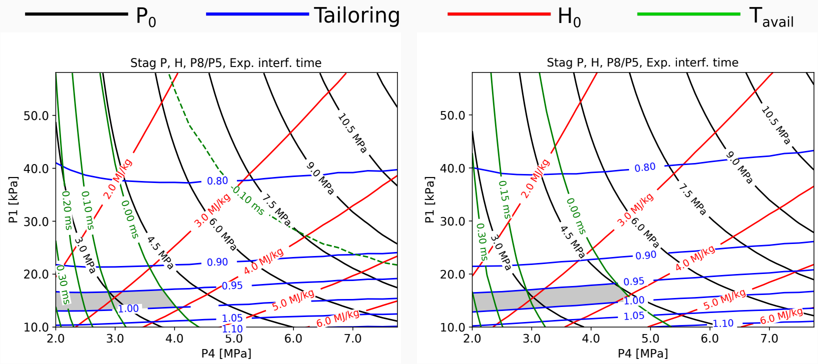
1x and 0.5x Piston mass.

Effect of Piston Mass



1x and 2x Piston mass.

Effect of Piston Mass

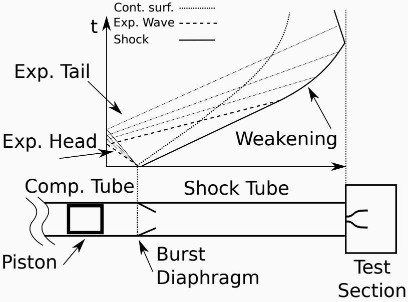


1x and 4x Piston mass.

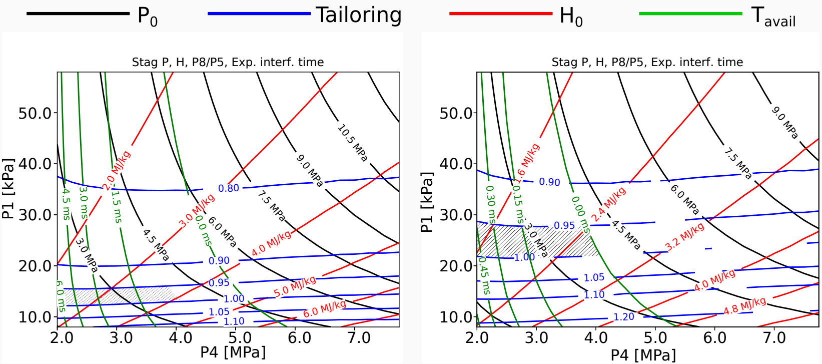
Questions?

Avoiding interference

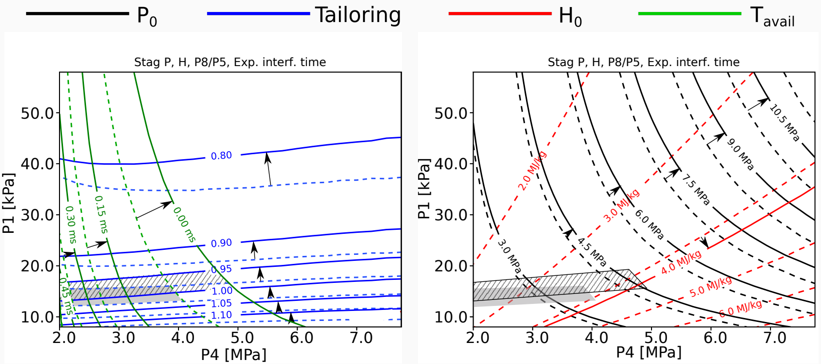
- Reduce compression ratio:
  - Reduce speed of sound in CT.
  - Increase piston distance to diaphragm.
- Obtained with:
  - max initial CT pressure.
  - max initial reservoir pressure.



Case with interference.



100%He and 95% He cases.



High losses vs Zero losses in launcher.