Impact of Air Injection on Jet Noise

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Fall Acoustics Technical Working Group
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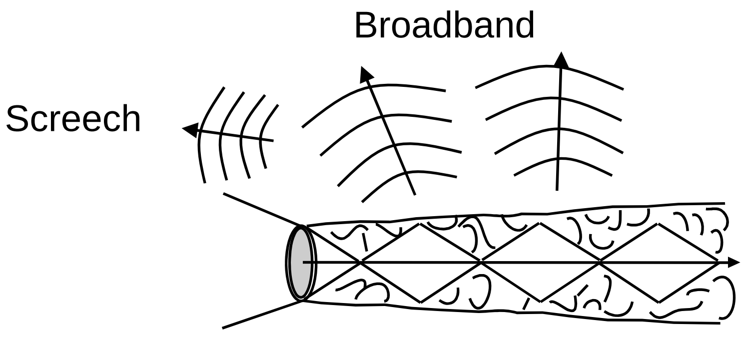
Objective

Determine impact of core fluidic chevrons on noise produced by dual stream jets

- Broadband shock noise - supersonic
- Mixing noise – subsonic and supersonic

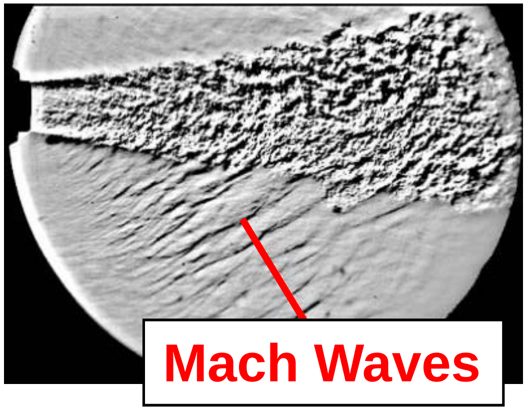
Jet Noise Sources

Shock Noise



Mixing Noise

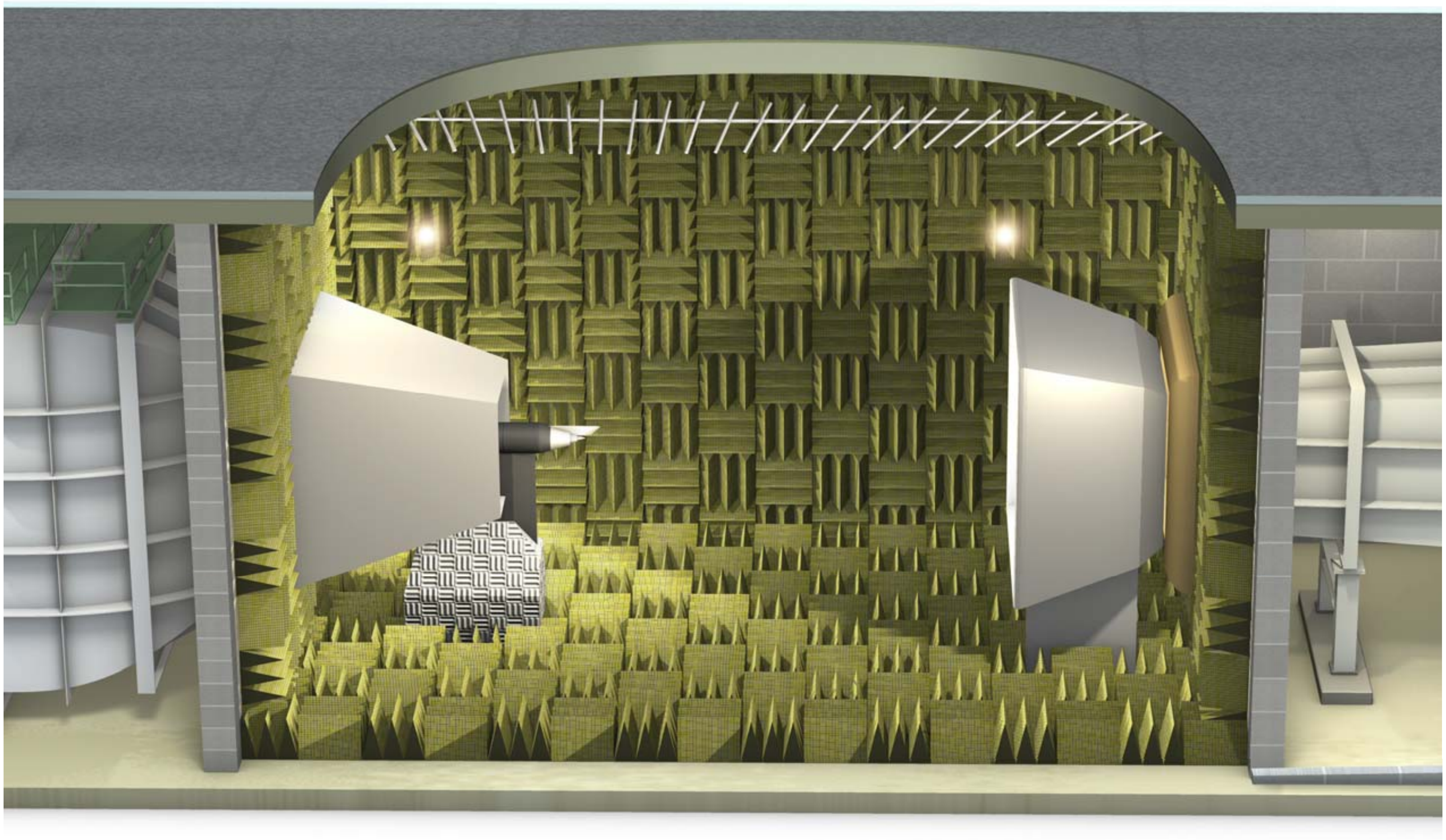
- Mixing noise
- Mach wave radiation
  - Crackle
- Shock associated noise
  - Broadband
  - Discrete
- STOVL noise/tones



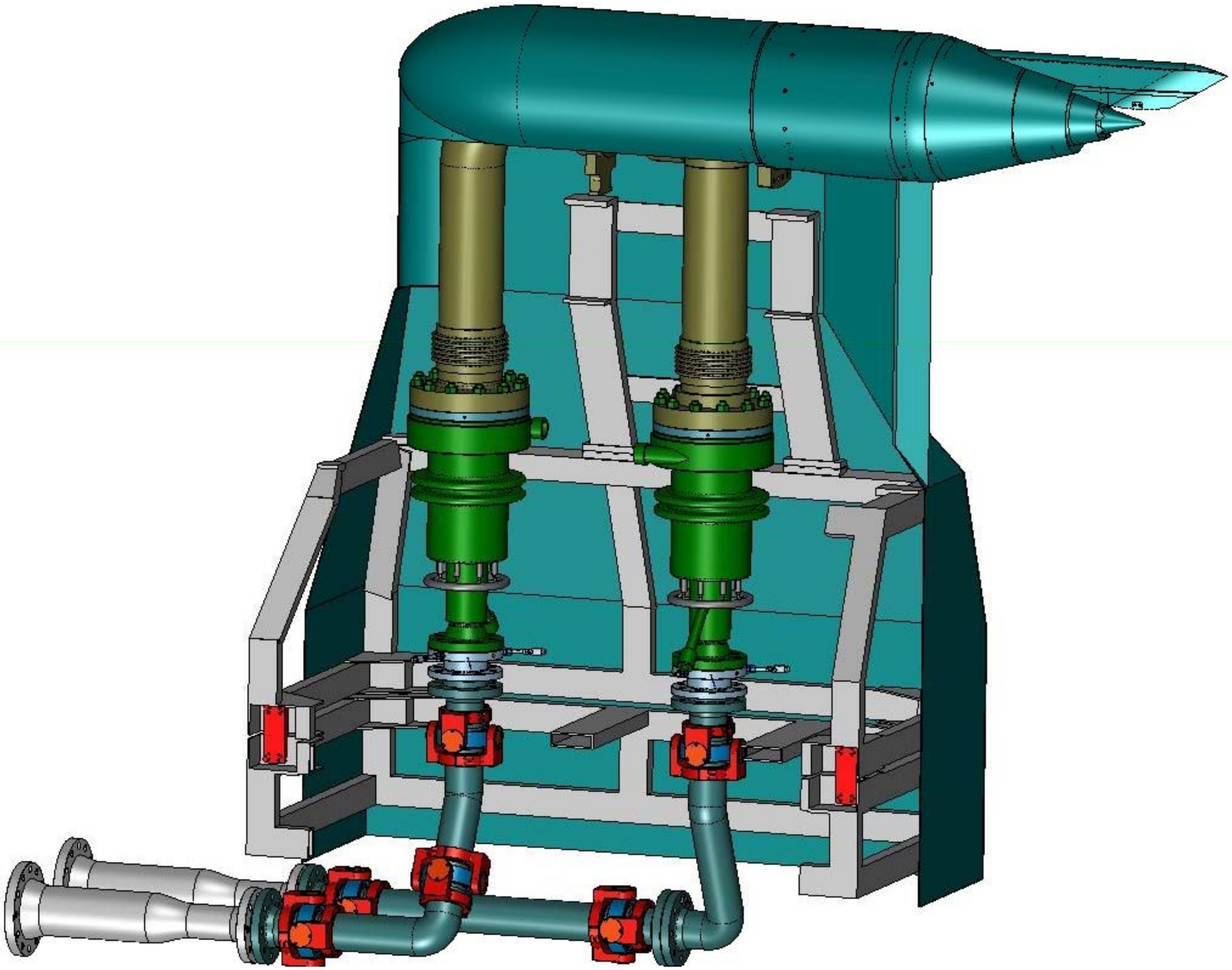
Courtesy of D. Papamoschou

NASA Langley (LSAWT)

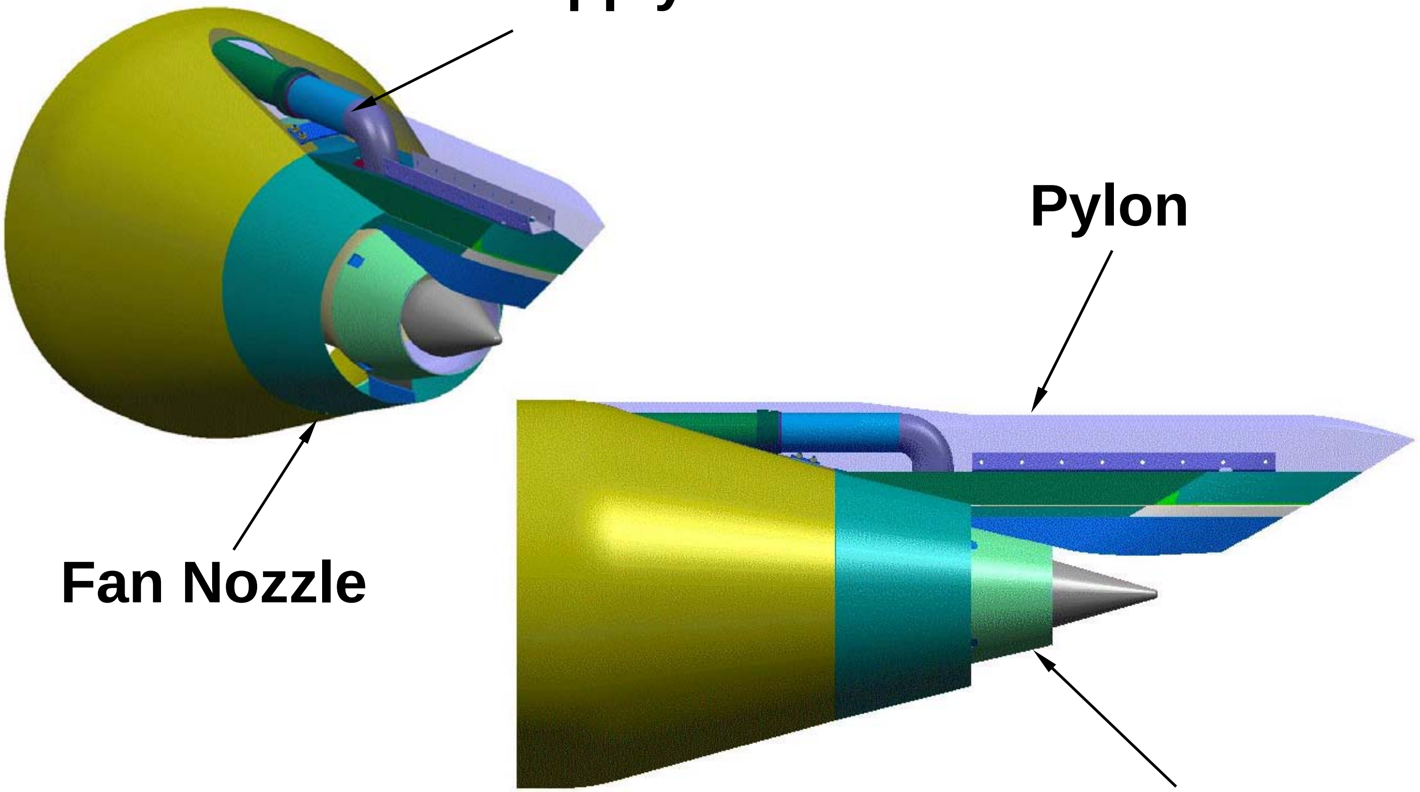
Low Speed Aeroacoustics Wind Tunnel



Jet Engine Simulator (JES)



Generation II Fluidic Chevrons



Air Supply

Pylon

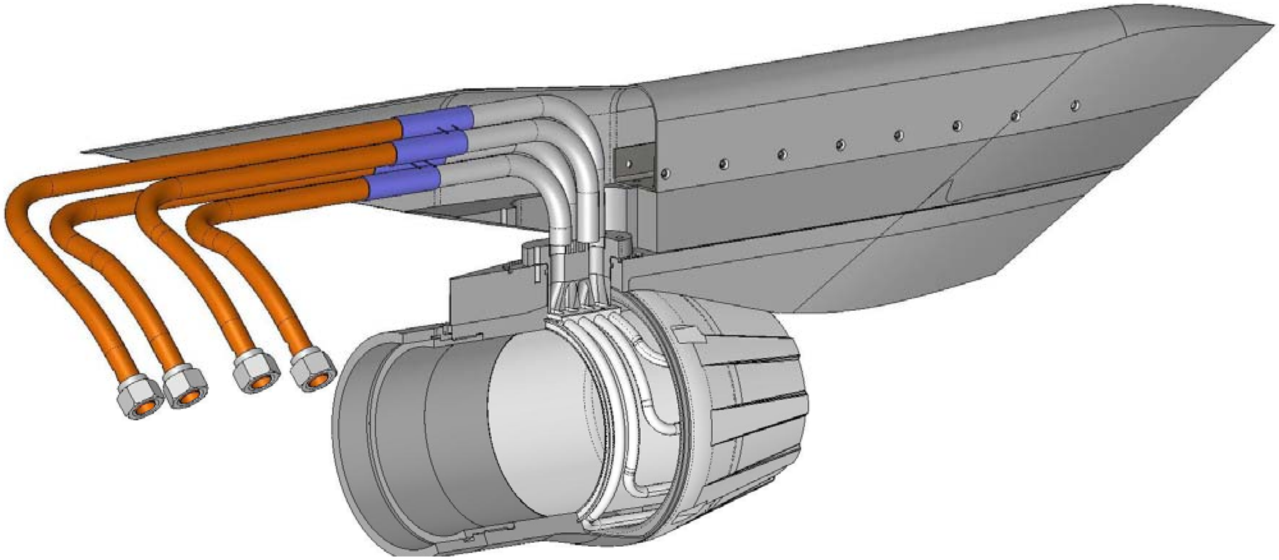
Fan Nozzle

Fluidic Chevron Core Nozzle

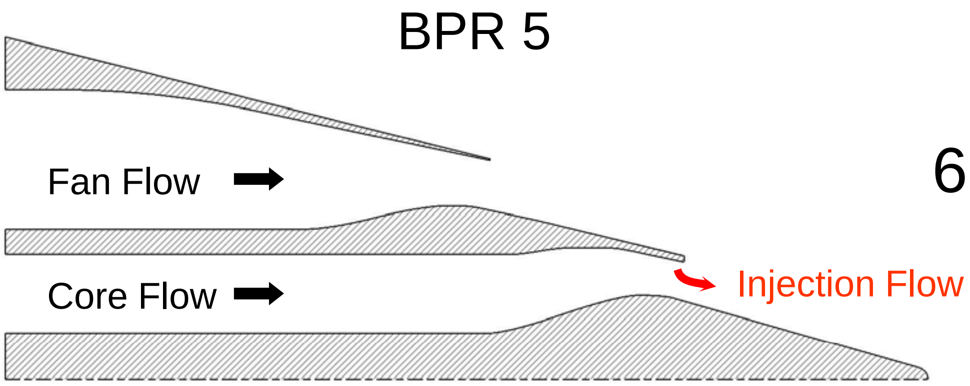
Nozzle design was the result of a partnership between NASA Langley Research Center and Goodrich Aerostructures under SAA1-561

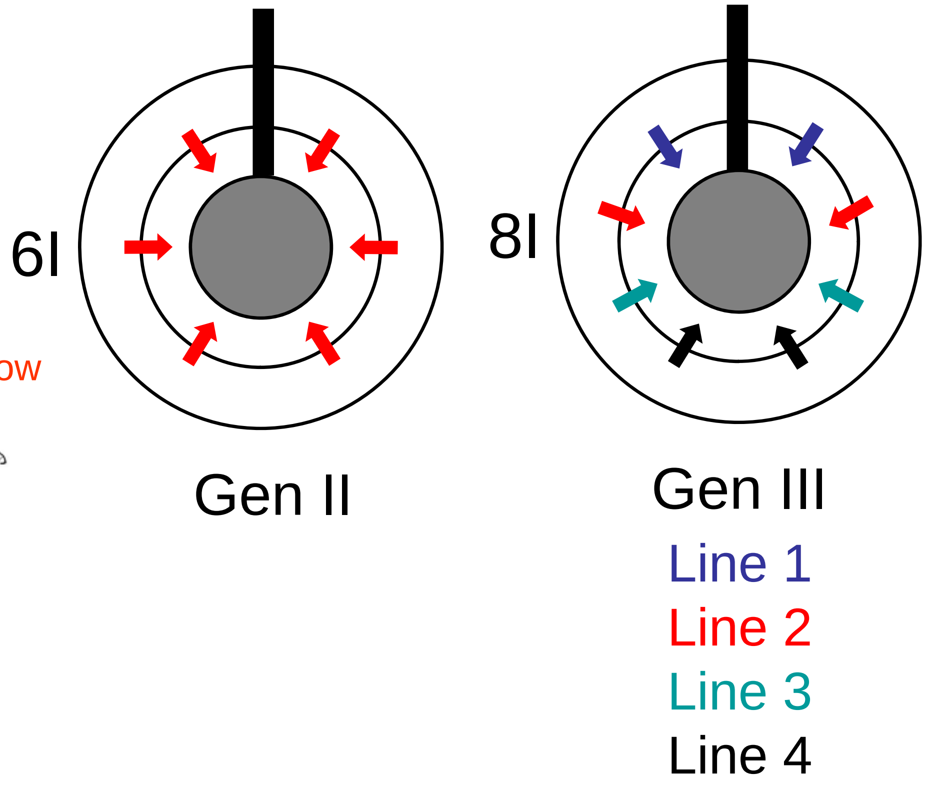
Generation III Fluidic Chevrons

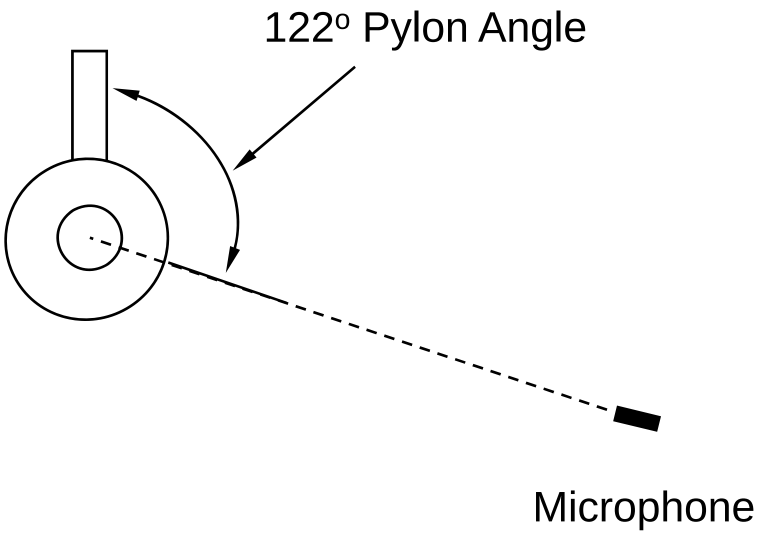
- Core fluidic chevron nozzle
- 8 injectors
  - 4 pairs independently controlled
- No common plenum



Fluidic Chevron Nozzles



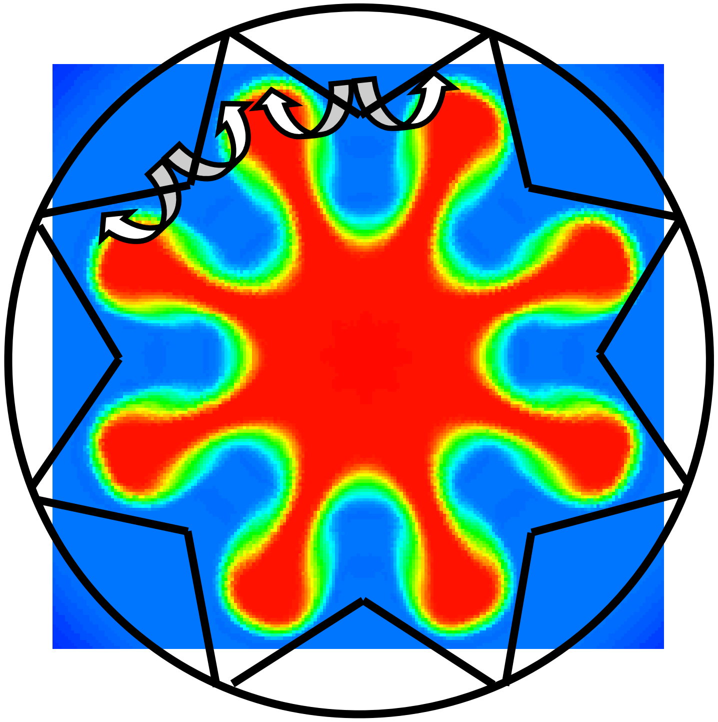


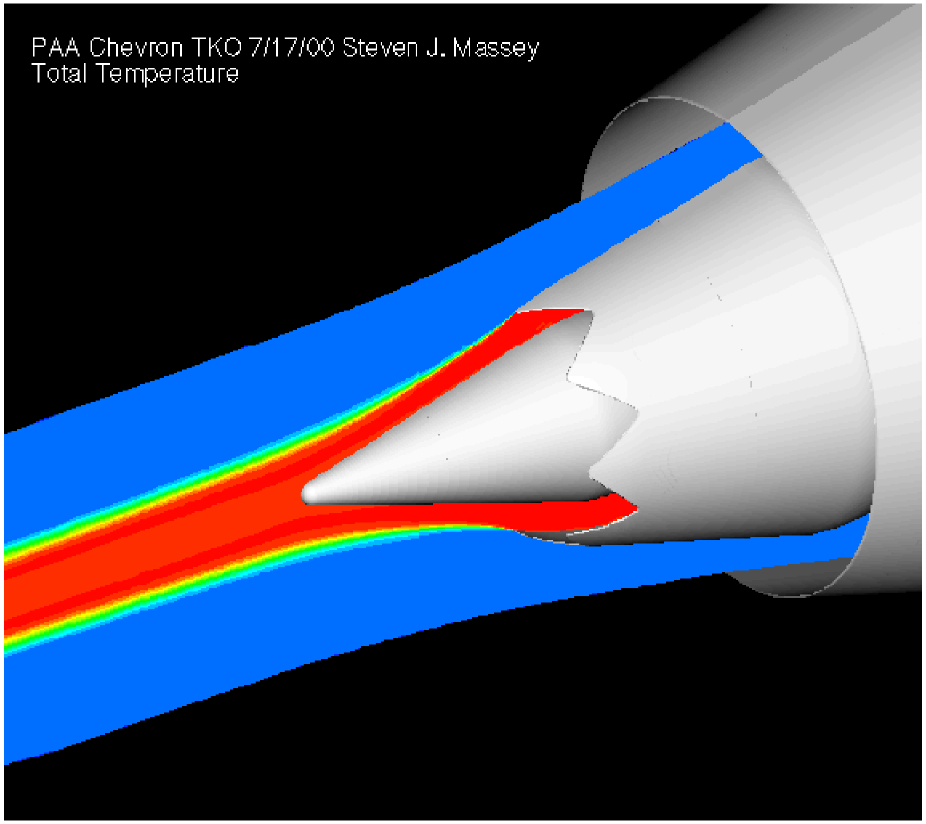


Three Air Injection Nozzles

- 6I steep injection
- 6I shallow injection
- 8I steep injection
  - – azimuthal control

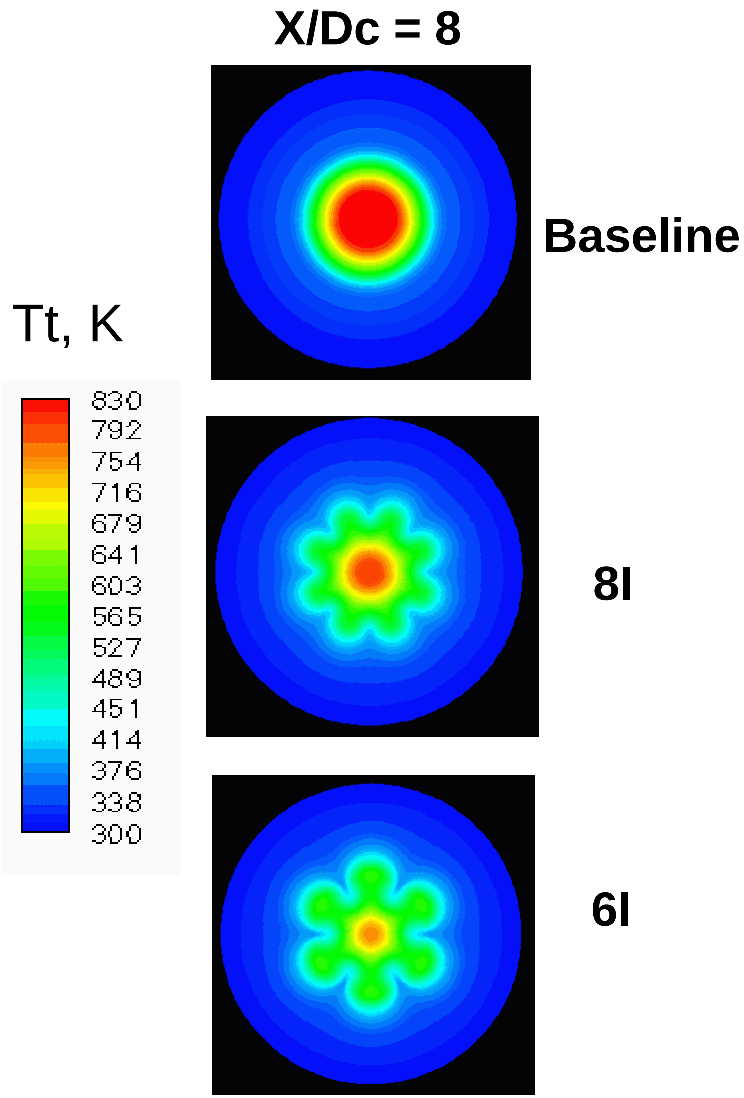
Chevron Mixing Enhancement

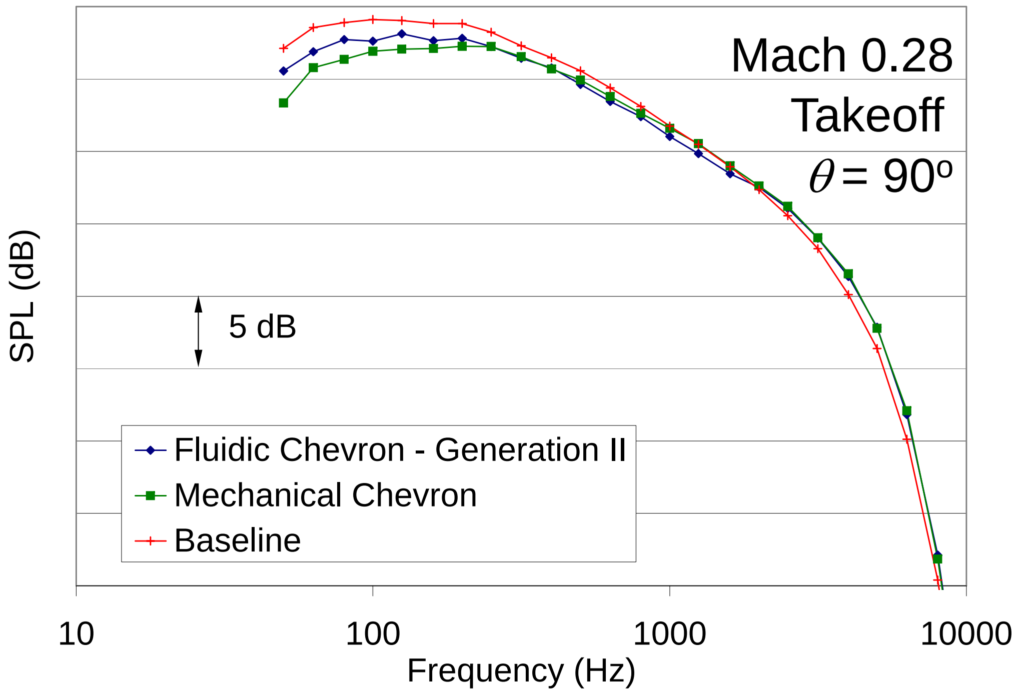




- Enhanced mixing shortens potential core and reduces volume of acoustic sources

Characteristics of Fluidic Chevrons





Experiments

NPR_c	TTR_c
1.93	1
2.04	1
2.17	1
2.30	2.5

Single Stream Experiments

- Fan stream operated at tunnel conditions

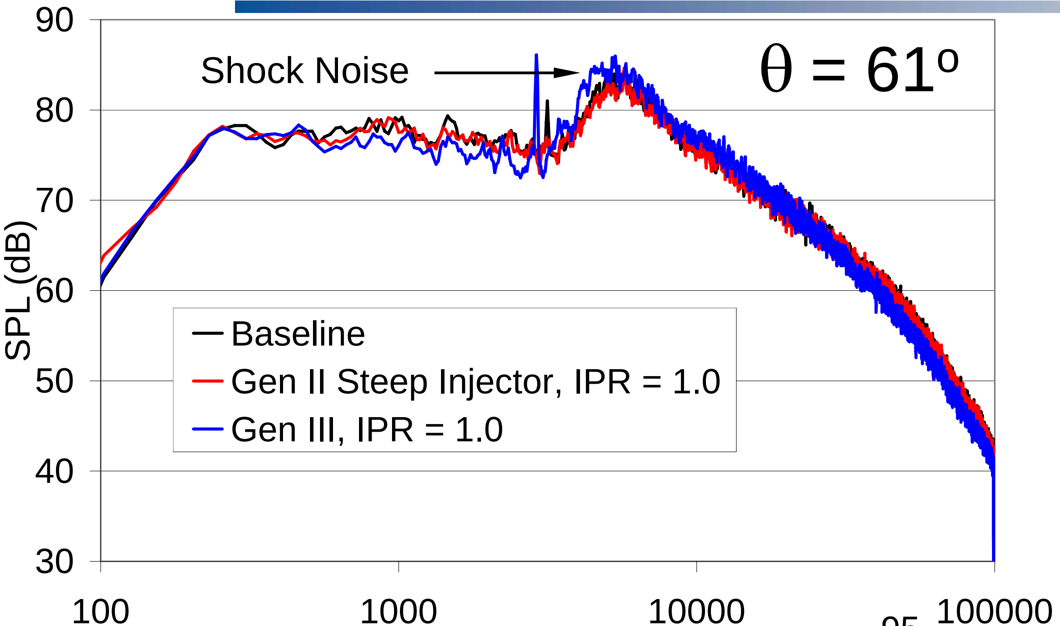
NPR_c	TTR_c	NPR_f	TTR_f
1.56	**2.66**	**1.75**	**1.16**
1.61	2.13	2.23	1.05
1.82	2.13	2.23	1.05
2.04	2.39	2.23	1.05
1.61	2.26	2.35	1.17
1.82	2.26	2.35	1.17
2.04	2.39	2.35	1.17
2.17	2.46	2.35	1.17
2.04	2.39	2.45	1.04
2.17	2.46	2.5	1.05

Dual Stream Experiments

Free-stream Mach number = 0.10

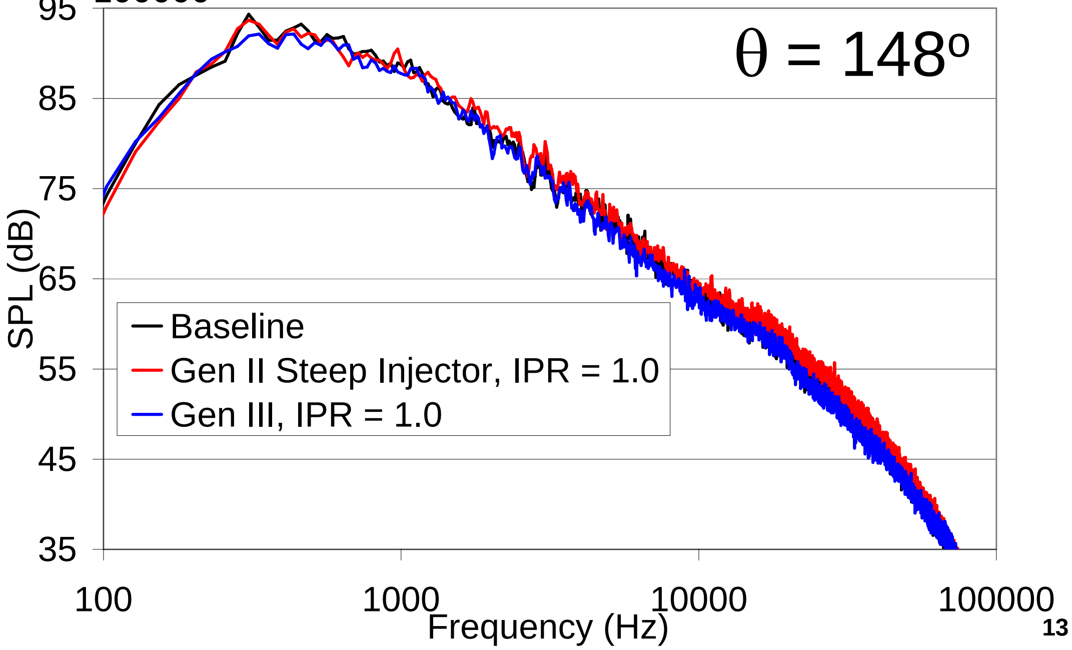
Single Stream Results

Baseline

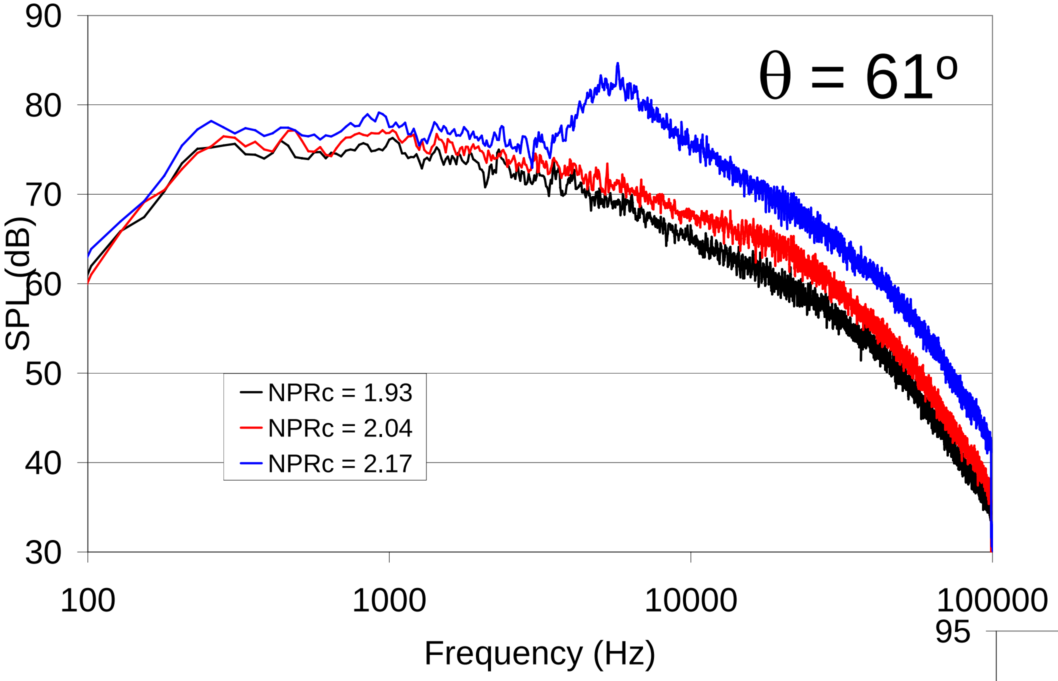


Baseline nozzle and injection nozzles with IPR = 1.0 have similar noise characteristics

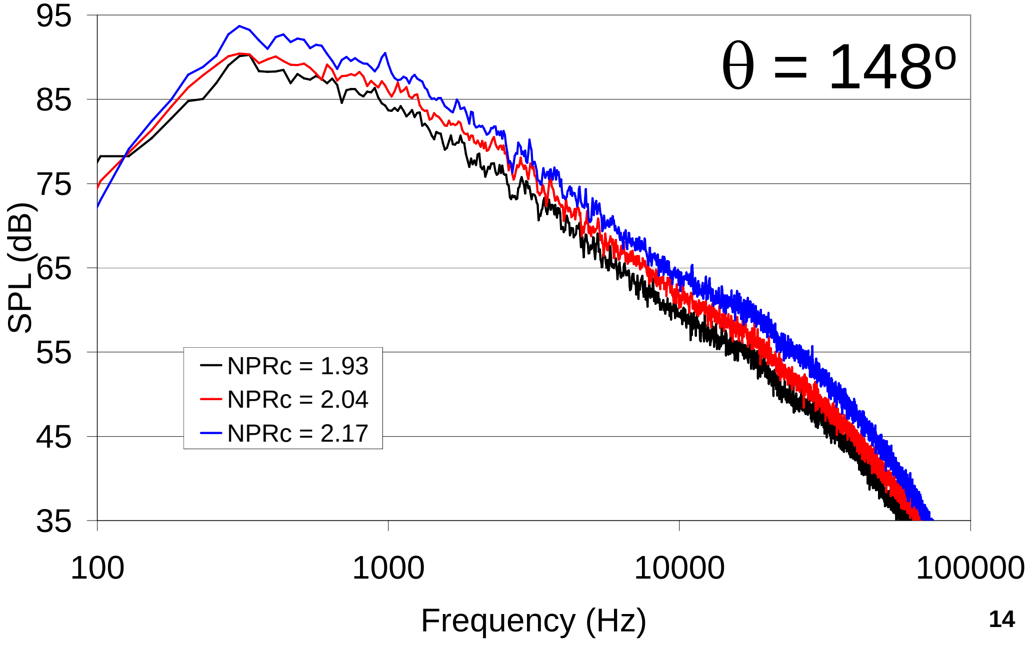
$NPR_c = 2.17$



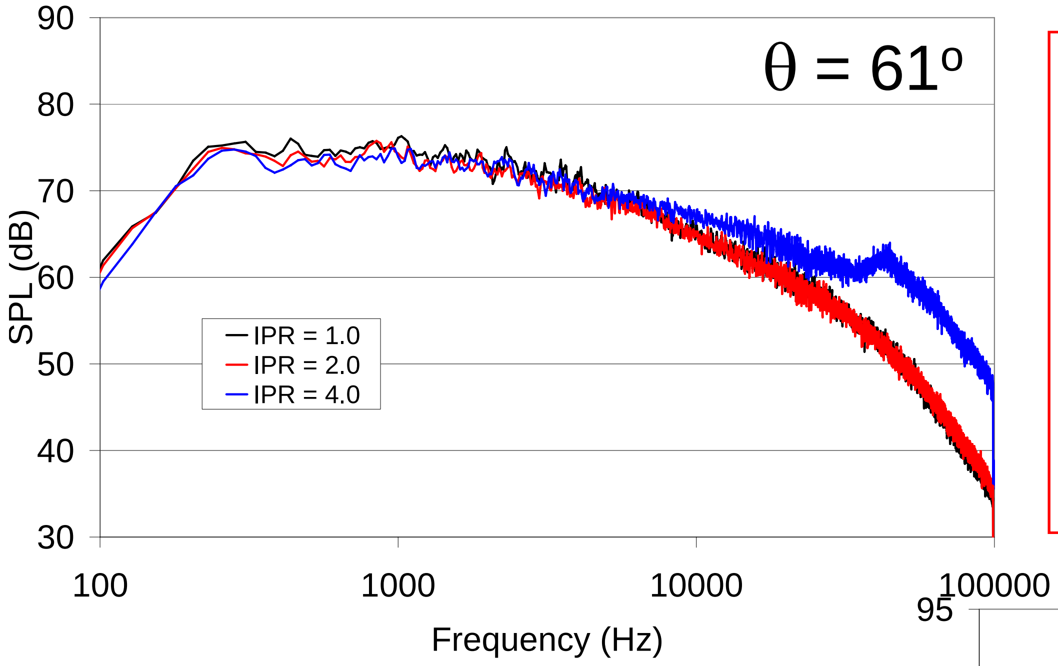
Effect of Increasing NPR_c



Well defined shock noise peak at $NPR_c = 2.17$

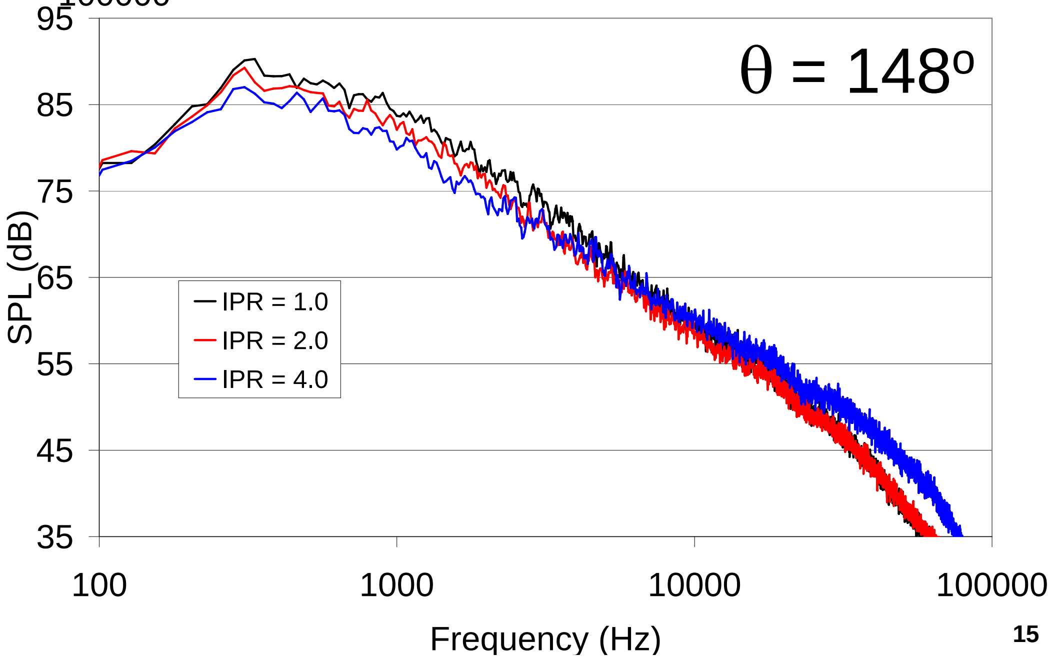


Injection at Low Supersonic Speeds

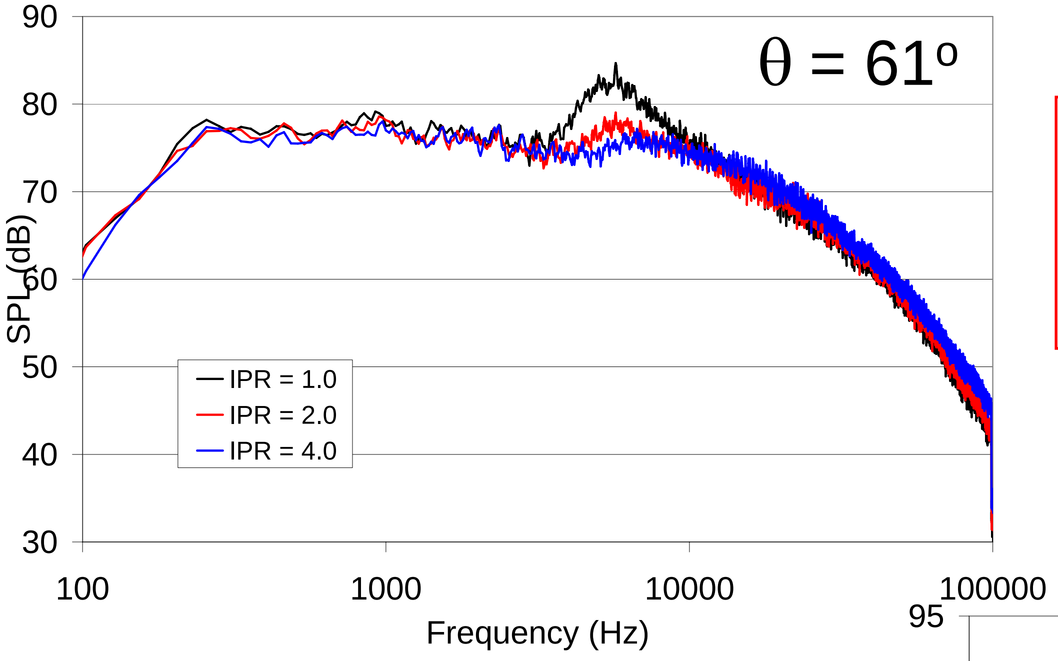


- Injector noise is is not suppressed
- Increases in IPR produce reductions in mixing noise near peak jet noise angle

$NPR_c = 1.93$

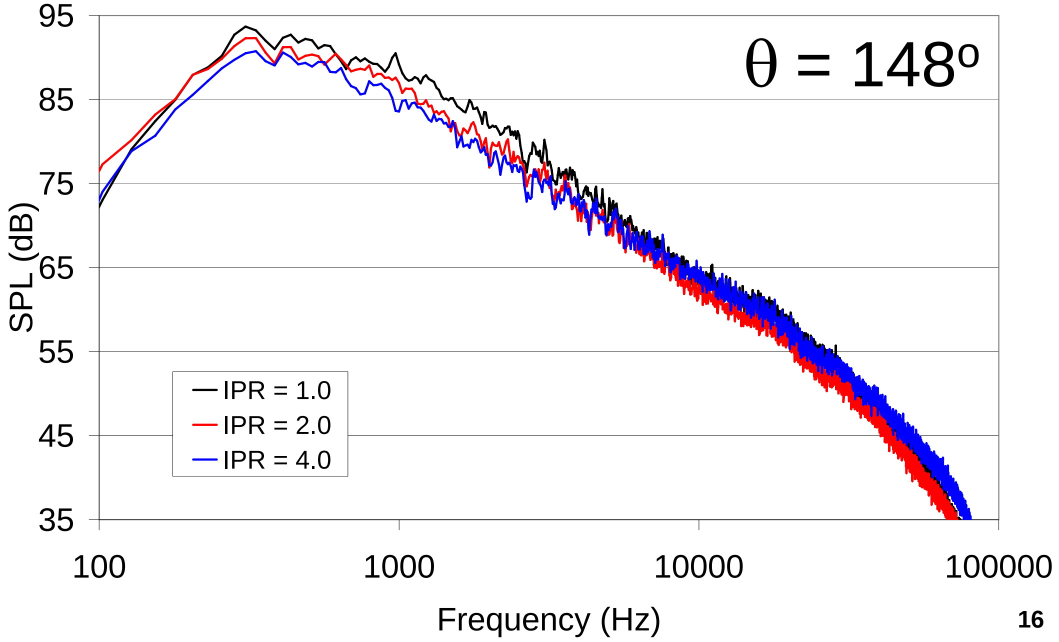


Injection for Well-Defined Shock Noise

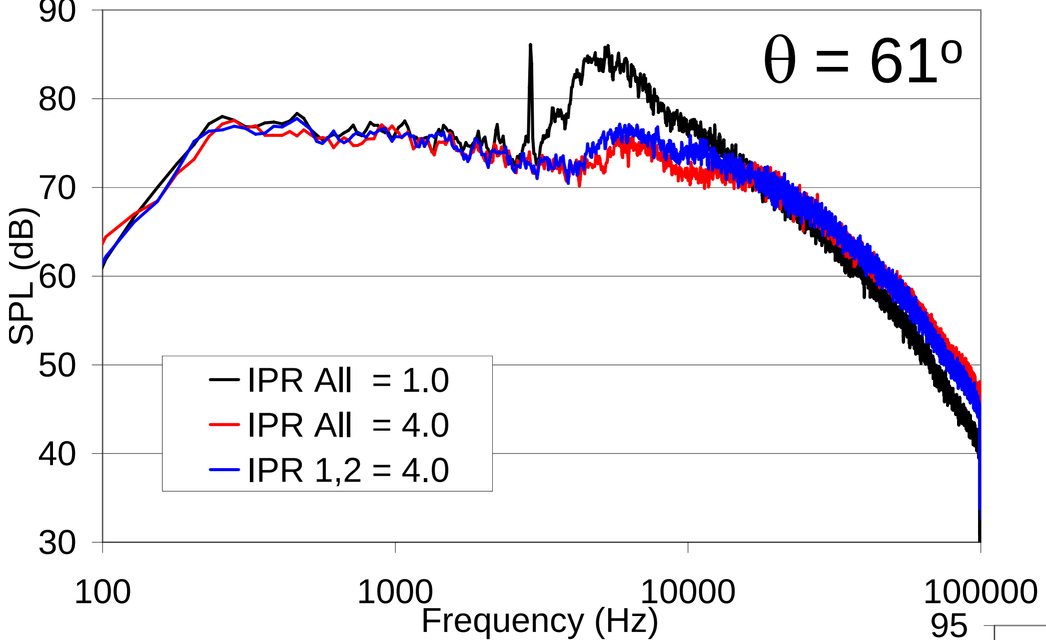


Increases in IPR produce reductions in shock noise and mixing noise

$NPR_c = 2.17$



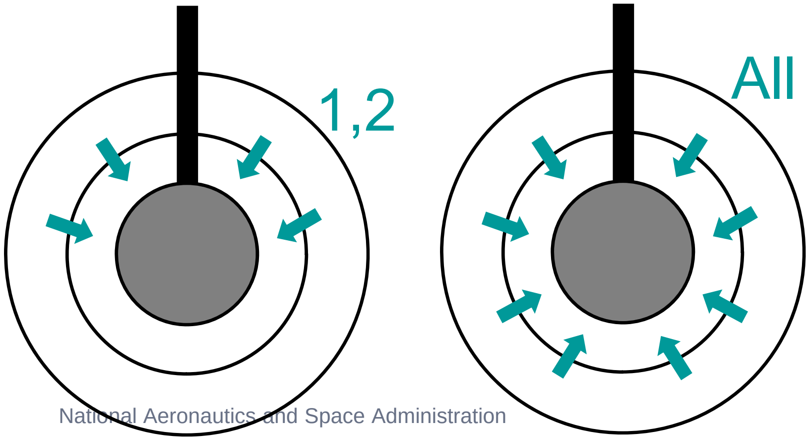
Azimuthal Control for Shock Noise

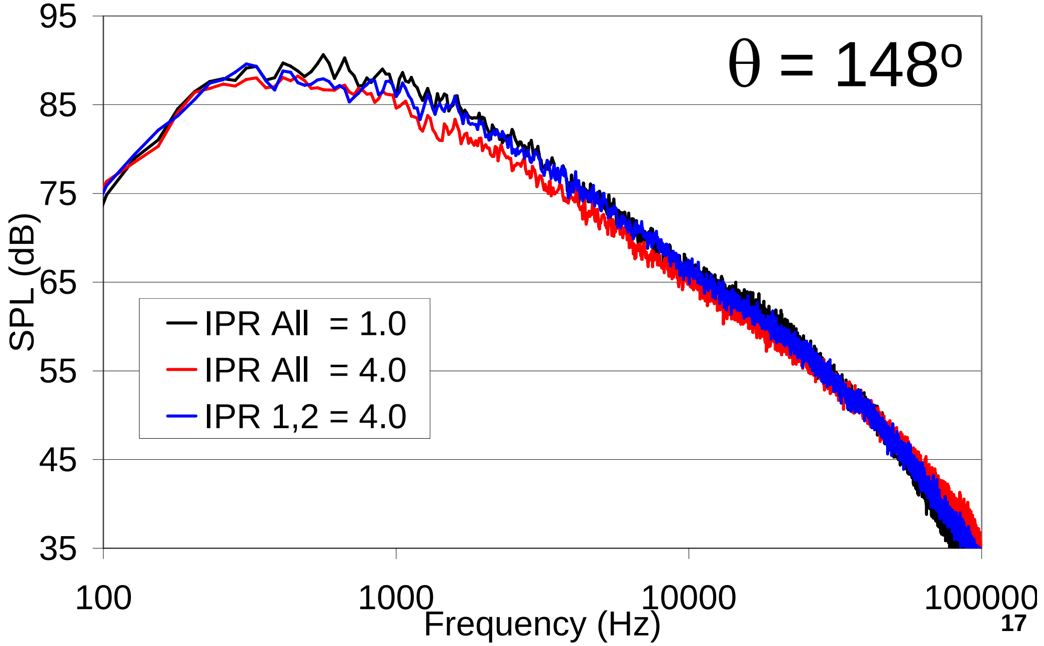


Significant shock noise reduction can be achieved with injection near pylon

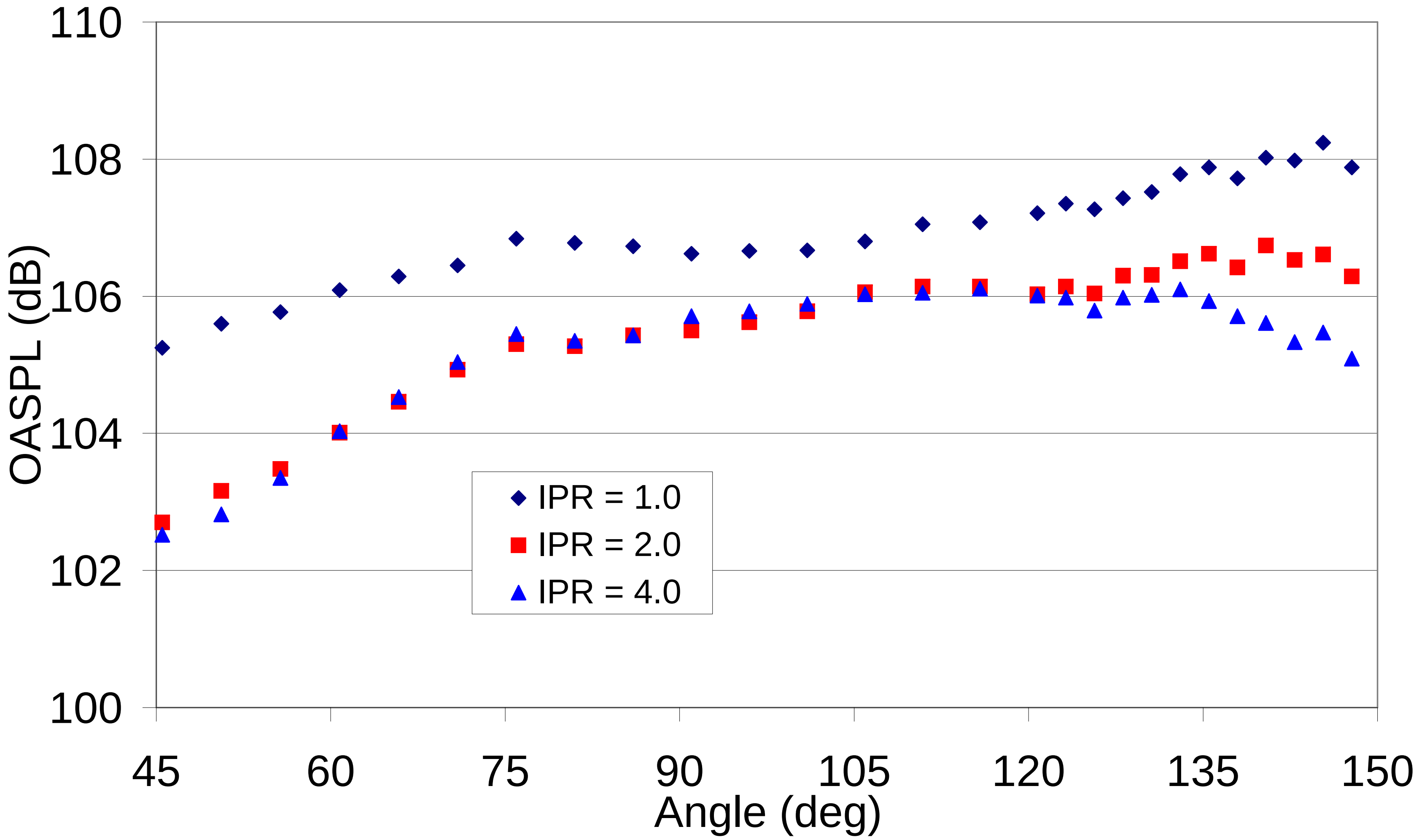
$$\frac{\dot{m}_{injection_{1,2}}}{\dot{m}_{core}} = 1.1\%$$

$NPR_c = 2.17$



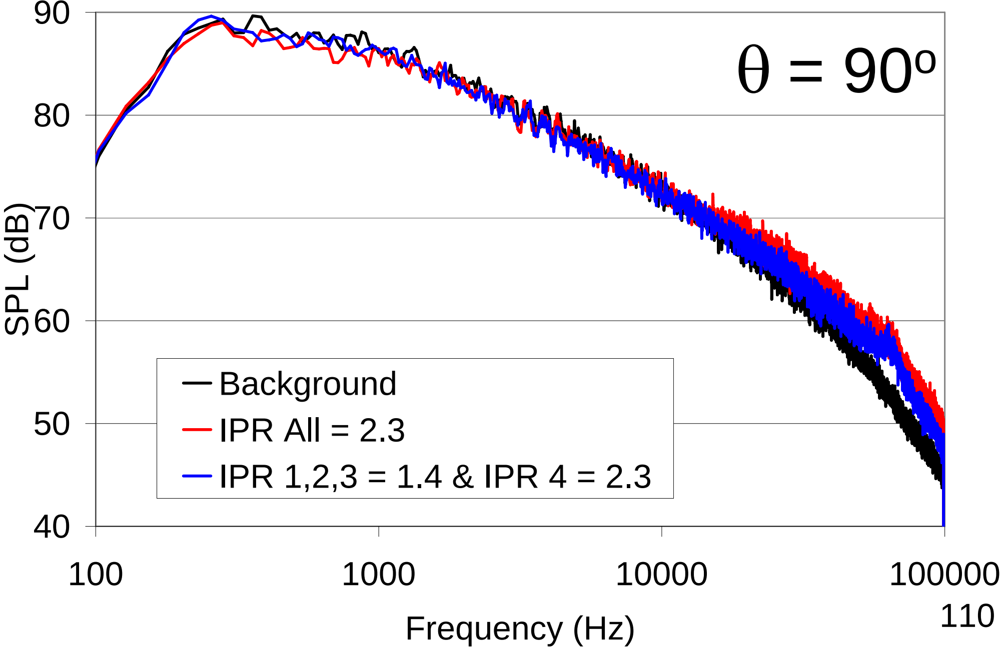


Impact of Injection on Sideline Directivity



Dual Stream Results

Injection at Subsonic Core and Fan Speeds

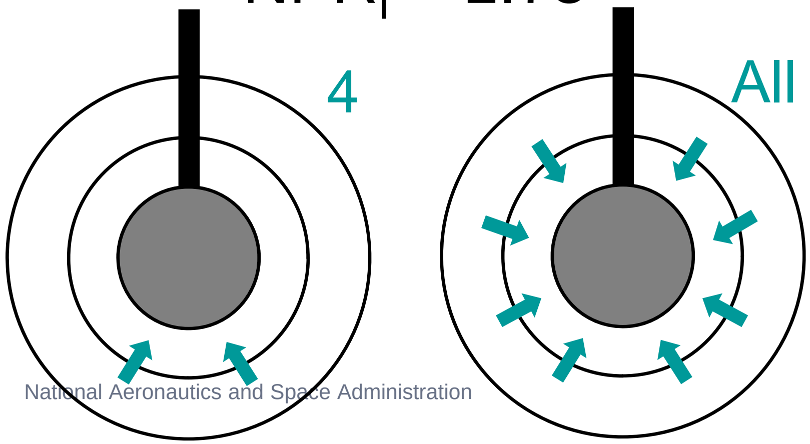


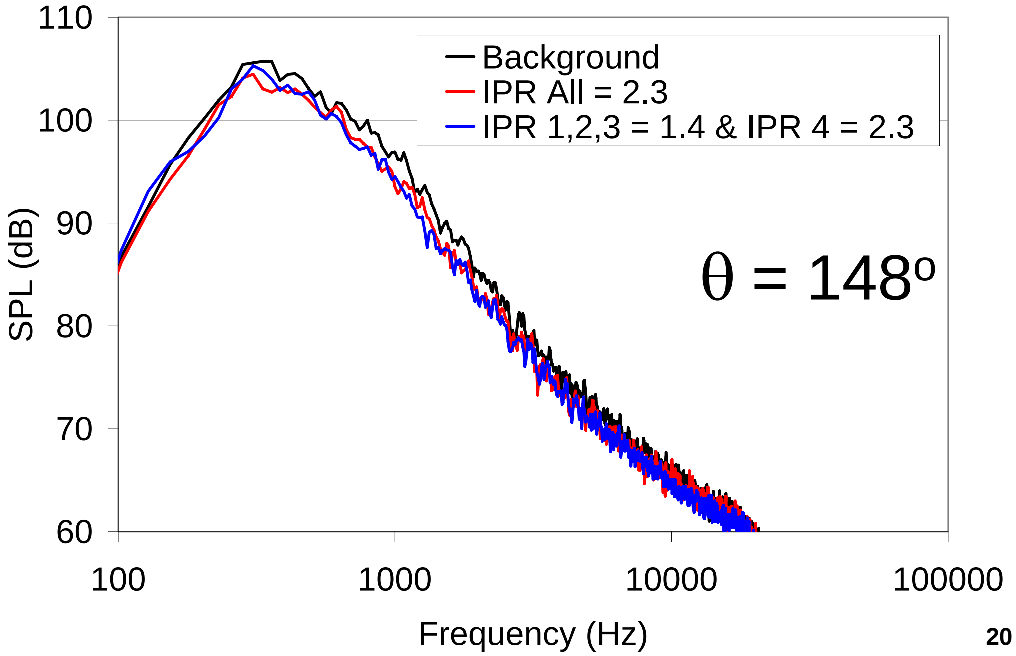
Mixing noise reduction can be achieved with injection near observation side of jet

$$\frac{\dot{m}_{injection_{1,2}}}{\dot{m}_{core}} = 1.6\%$$

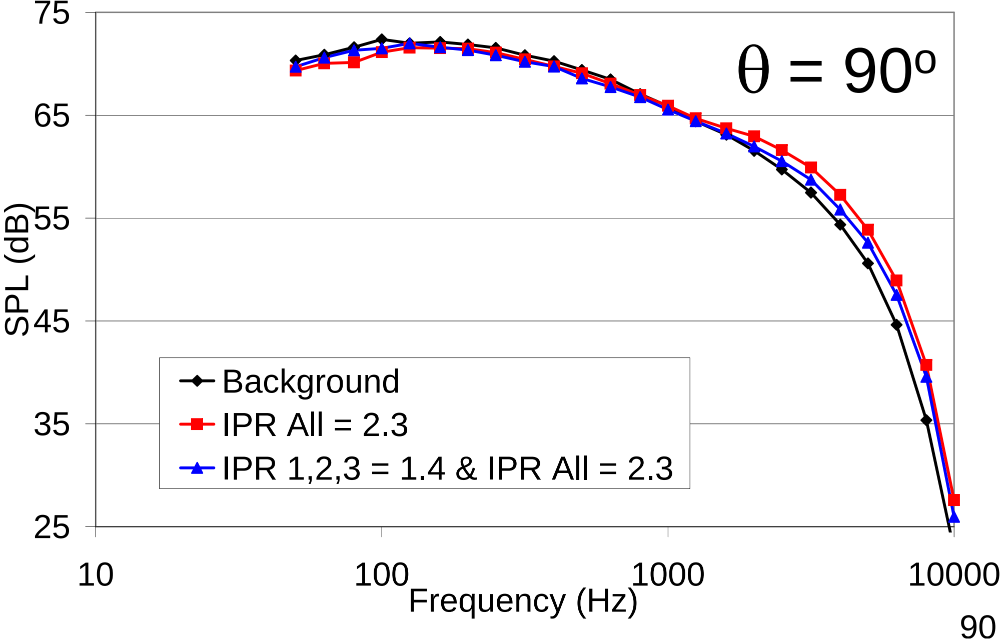
$NPR_c = 1.56$

$NPR_f = 1.75$





Injection at Subsonic Core and Fan Speeds

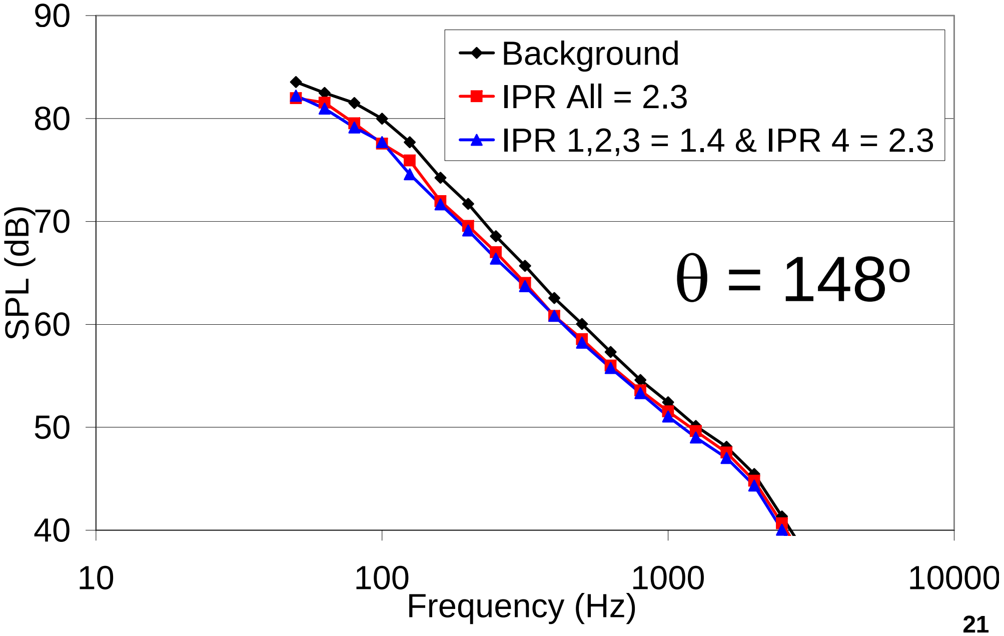


Injection produces mixing noise reduction at peak jet noise angle with slight increase in high frequency noise at 90º

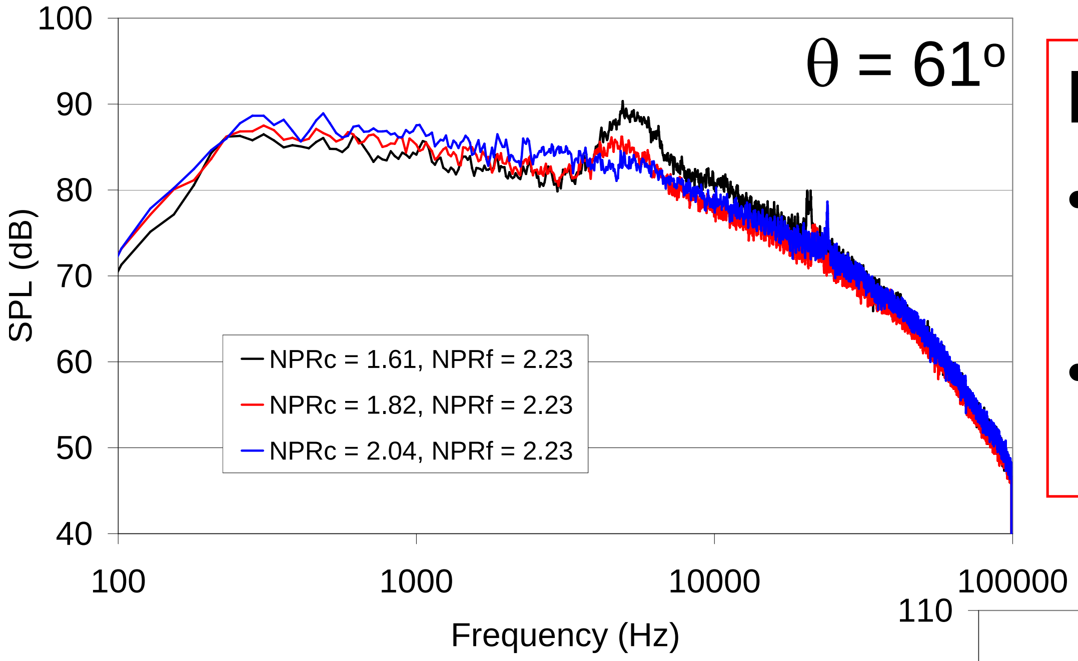
$NPR_c = 1.56$

$NPR_f = 1.75$

Nozzle	IPR	EPNL (EPNdB)	Injection Mass (% Core)
Baseline		90.4	
Air Injection	All = 2.3	89.6	2.9
Air Injection	1,2,3 = 1.4 & 4 = 2.3	89.4	1.6

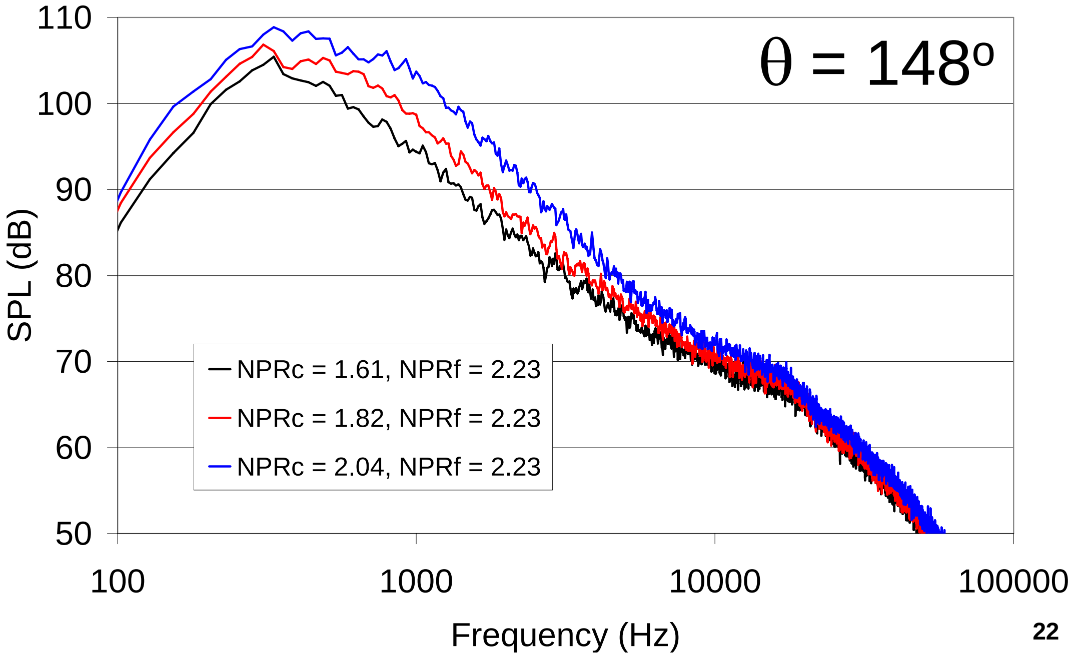


Baseline Results at $NPR_f = 2.23$

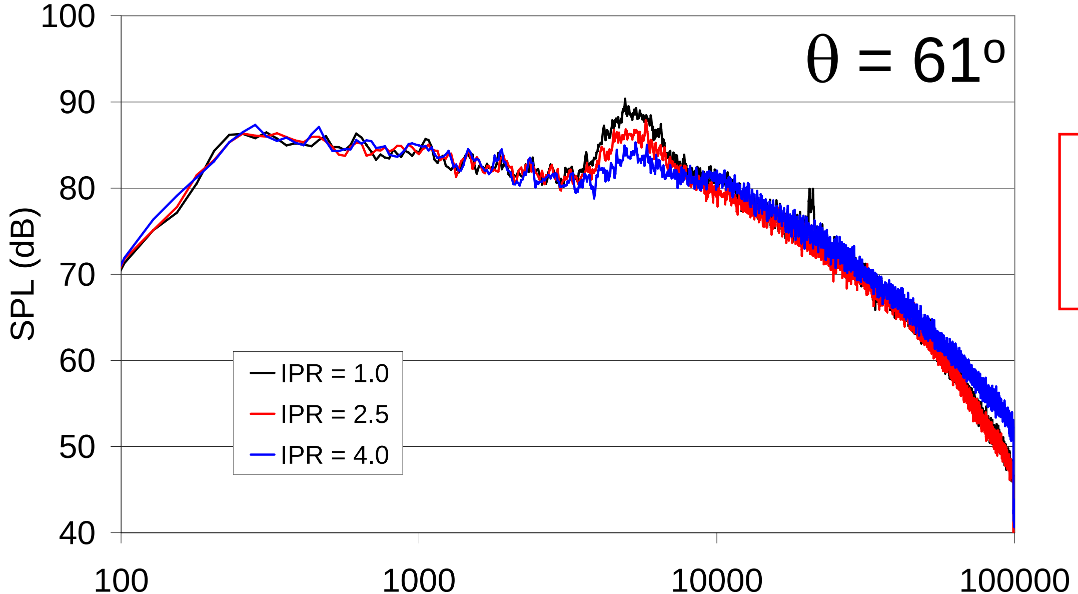


Increasing NPR_c

- Decreases shock noise peak
- Increases mixing noise near peak jet noise angle



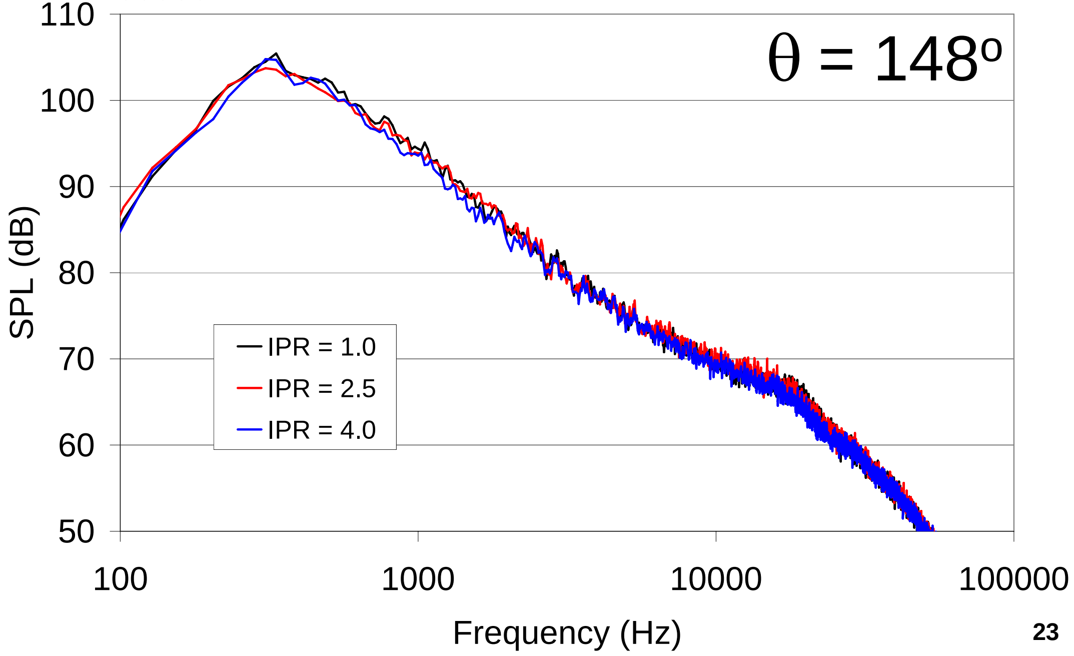
Injection at Subsonic Core Speeds



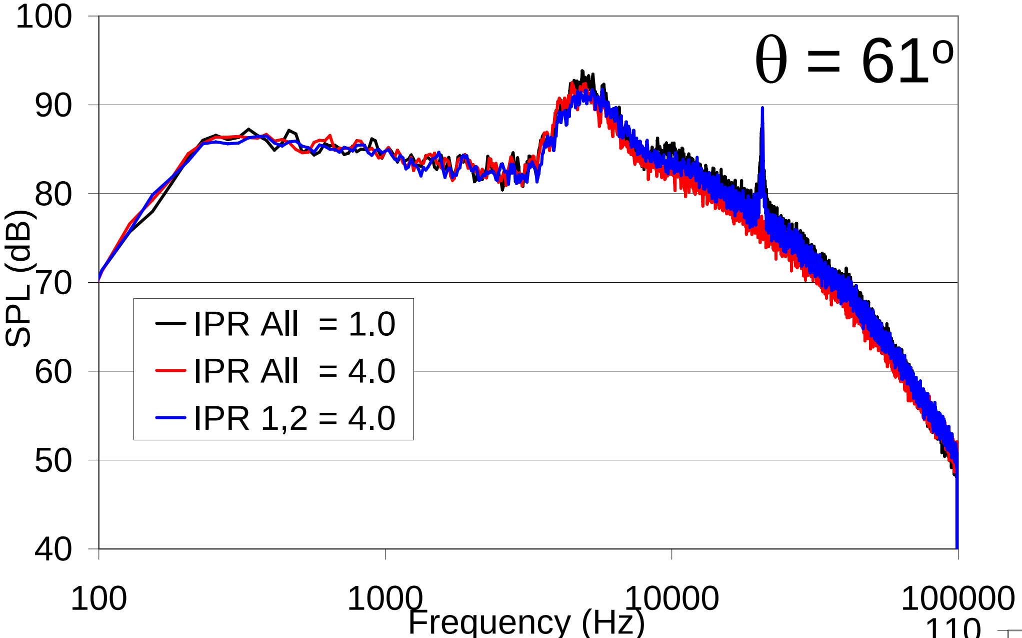
Increasing IPR decreases shock peak

$NPR_c = 1.61$

$NPR_f = 2.23$



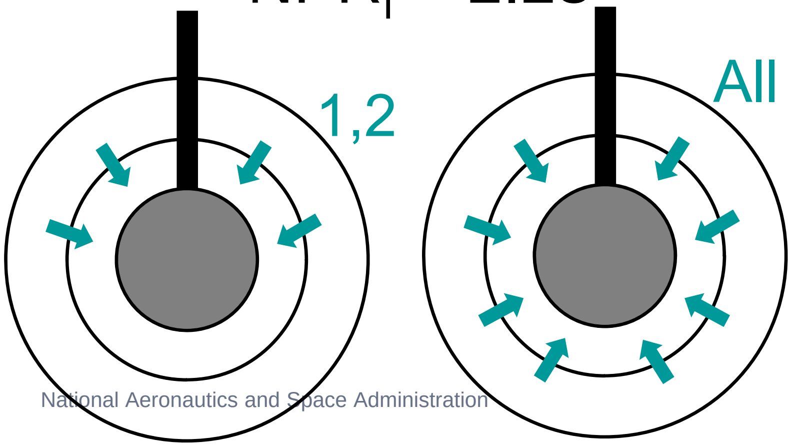
Azimuthal Control at Subsonic Core Speeds

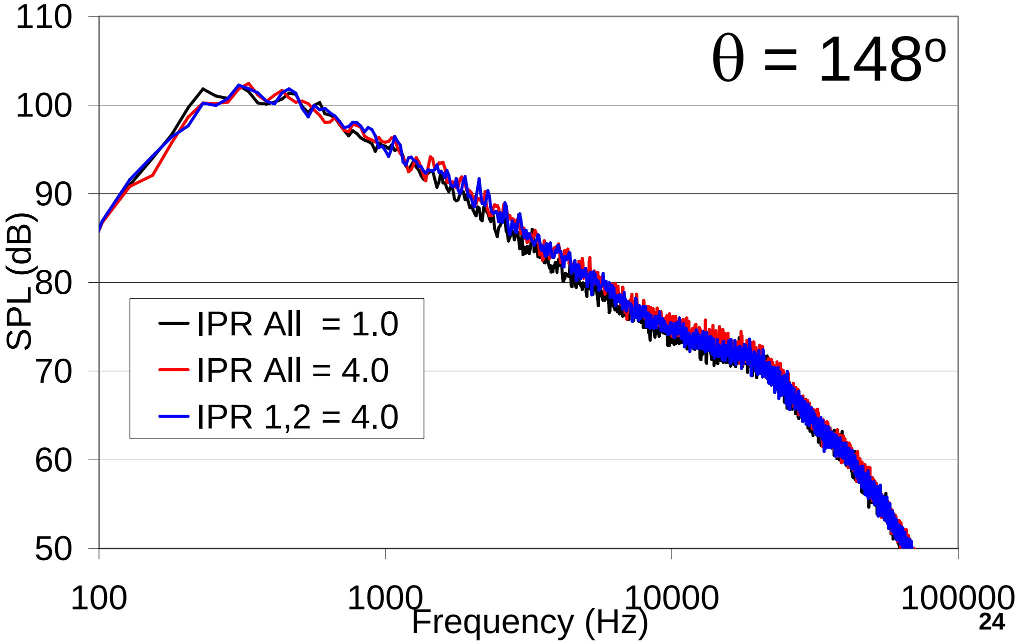


No noise reduction with Gen III nozzle due to low mass flow rates or steeper injectors

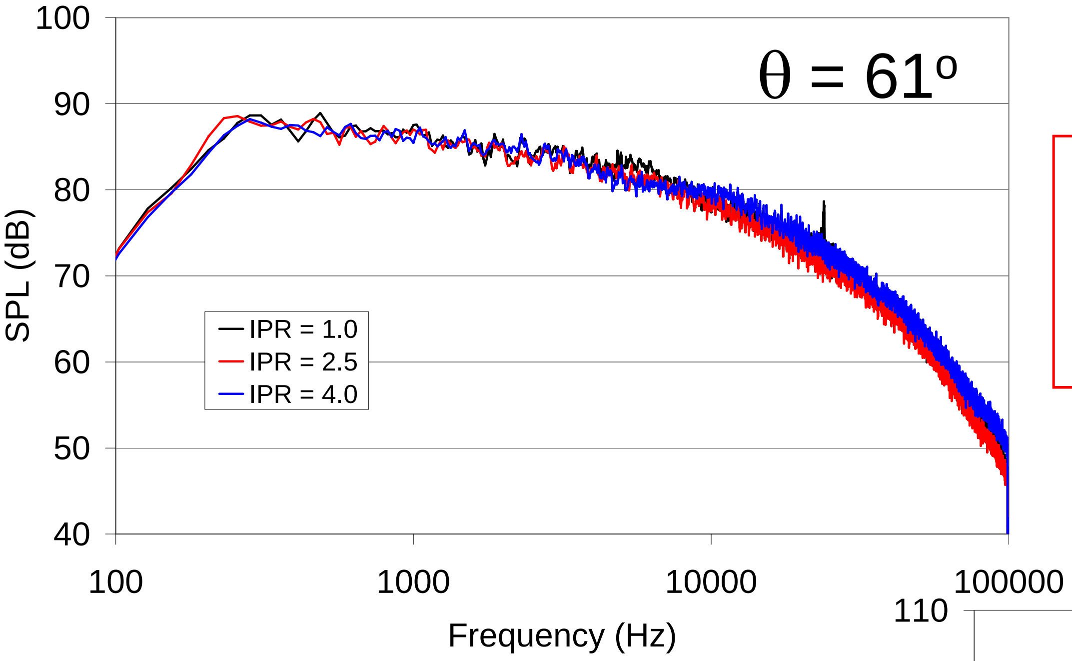
$NPR_c = 1.61$

$NPR_f = 2.23$





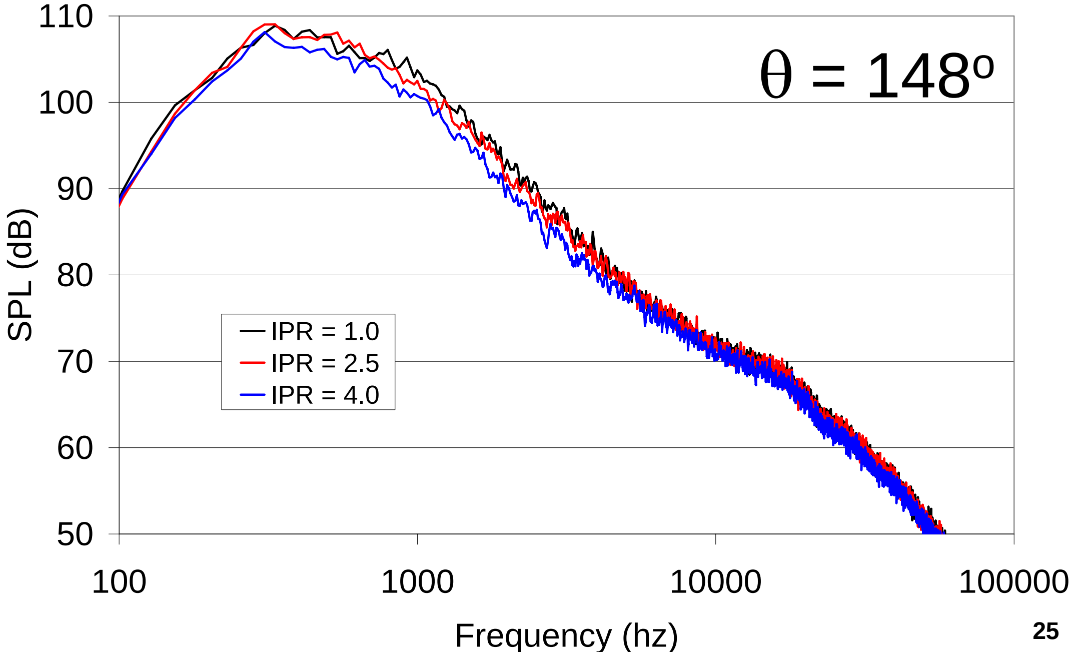
Injection at Supersonic Core Speeds



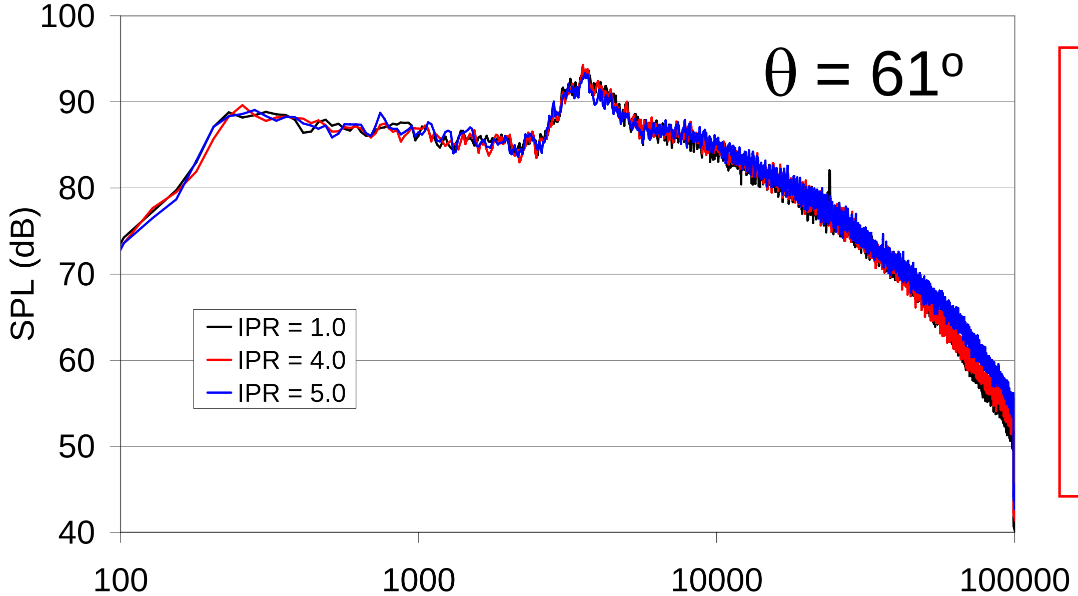
Increases in IPR produce reductions in noise near peak jet noise angle

$NPR_c = 2.04$

$NPR_f = 2.23$

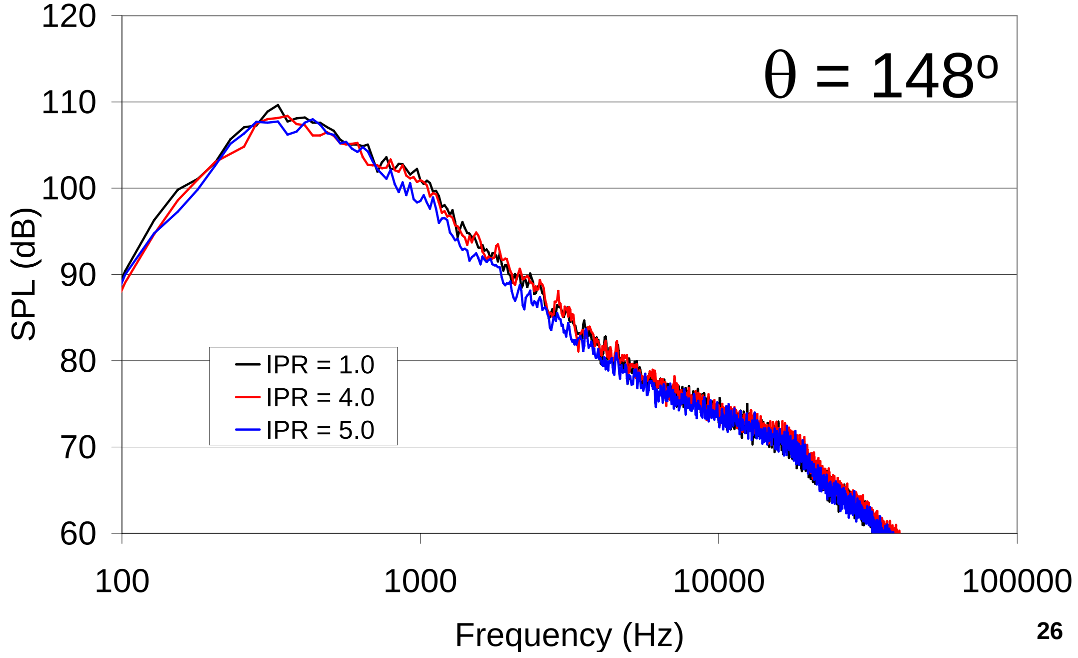


Injection at Subsonic Core Speeds



Increasing IPR

- Has no impact on broadband shock noise
- Slightly reduces noise at peak jet noise angle



$NPR_c = 1.82$

$NPR_f = 2.35$

Points of Discussion

- Injection impacts shock structure and stream disturbances through enhanced mixing
  - May impact constructive interference between acoustic sources
- High fan pressures may inhibit mixing produced by core injectors
  - Fan stream injection may be required for better noise reduction

Future Plans

- Modification of Gen II nozzles to allow for some azimuthal control
  - Will allow for higher mass flow rates
  - Will allow for shallower injection angles
- Flow field study – spring, 2008
- CFD analysis of flow

Conclusions

- Injection can reduce well-defined shock noise
- Injection reduces mixing noise near peak jet noise angle