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Throat Curvature For Improved Density Profile Optimization Of Supersonic Gas Jet Targets

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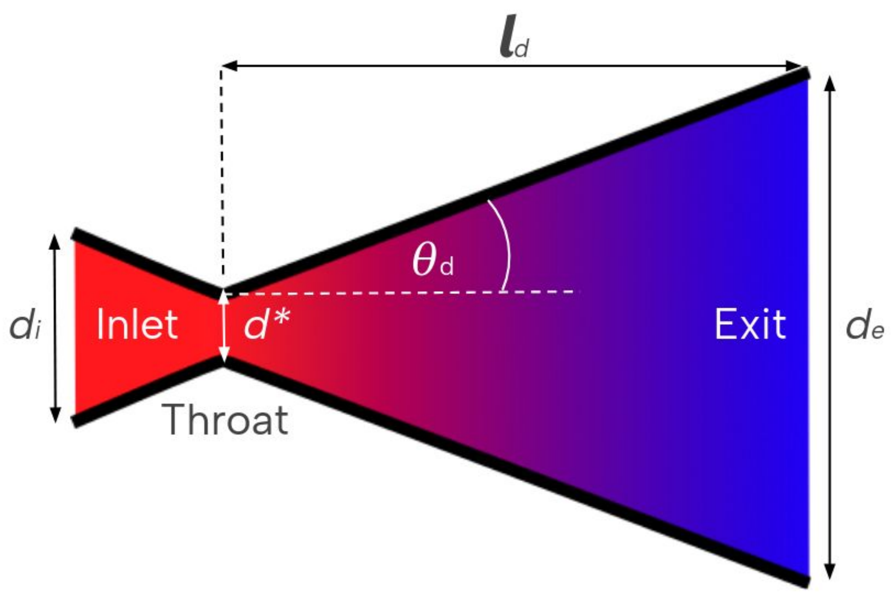
Supersonic gas jet nozzles

A common way of producing under-dense targets for laser-plasma interactions especially for high repetition rate systems.

Defined primarily by the main dimensions:

- Exit diameter d_e,
- Throat diameter d*
- Nozzle length l_d.



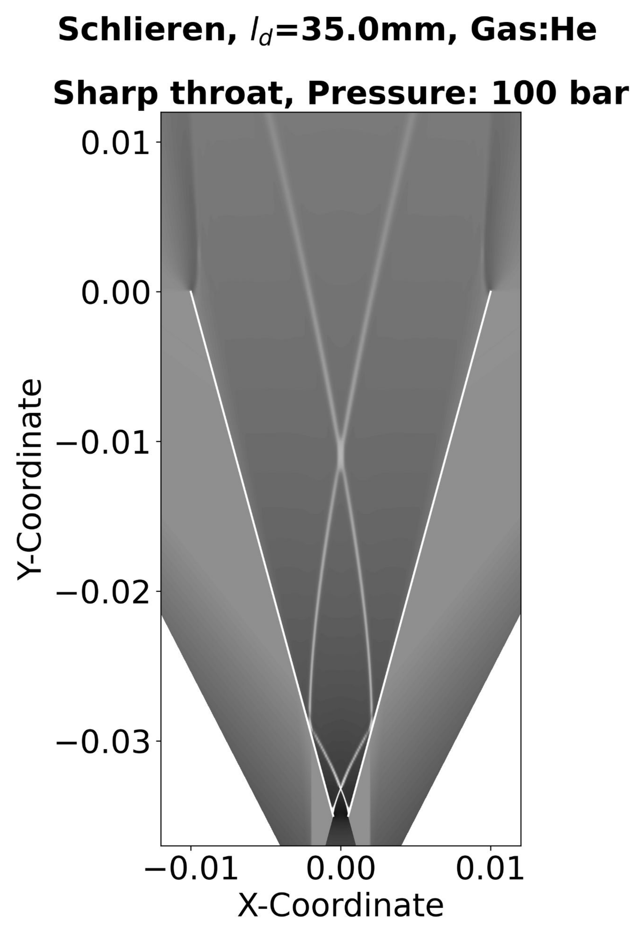
We include R*, for throat curvature.

Throat Shocks

Shocks are formed at the throat of all supersonic gas jets.
These shocks can form strong transitions in the density profile.

Traditionally the effect of these shocks has been mitigated by optimizing the ratios of the main dimensions, d_e, d* & l_d.

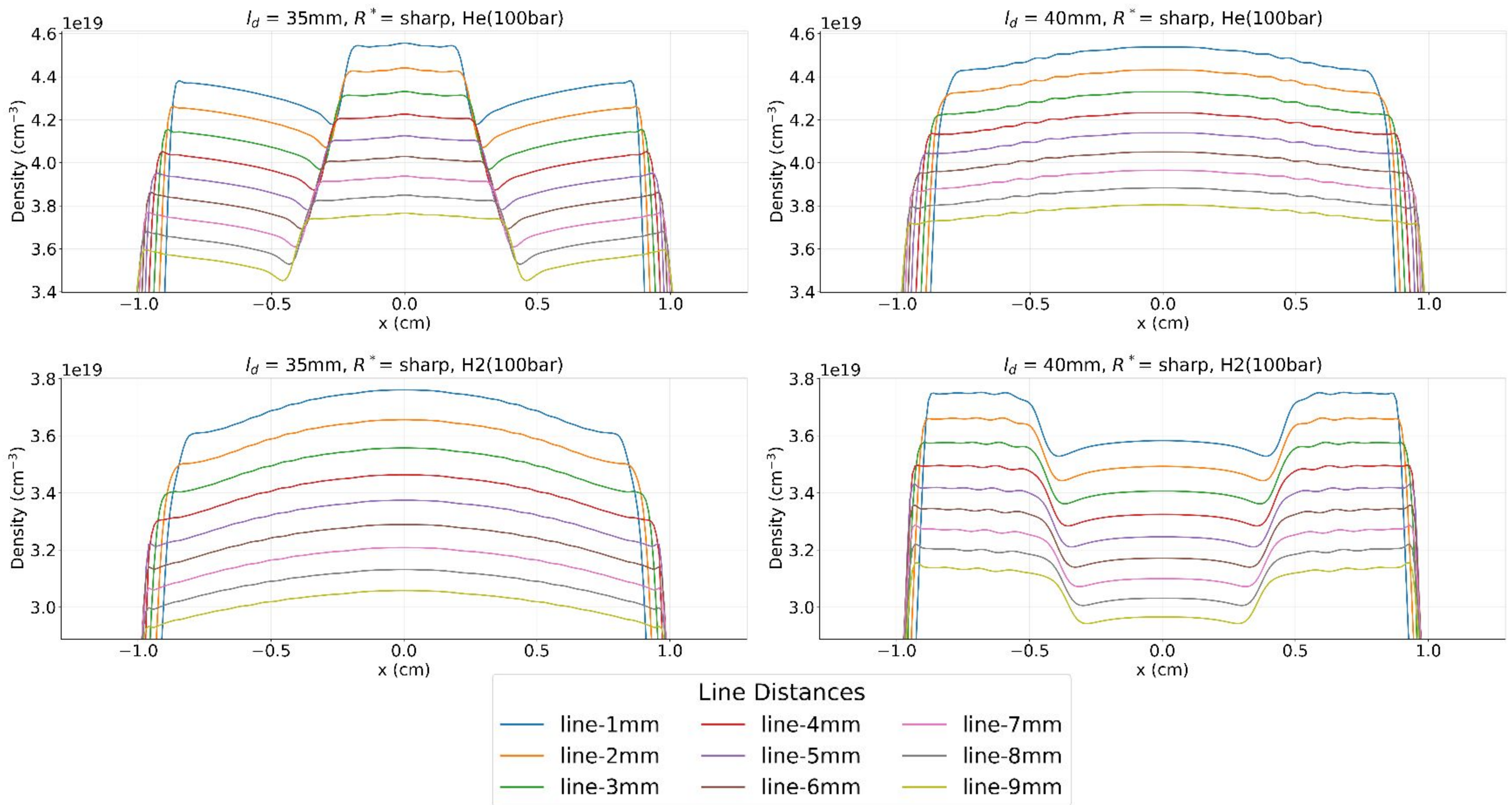
This aims the shocks to just miss the lip of the nozzle.



Monatomic Vs Diatomic

Due to extra degrees of freedom in the molecules H2, and N2, behave differently to the monatomic gasses.

The throat shocks follow different paths and so an optimized nozzle for one gas is not necessarily optimized for another.

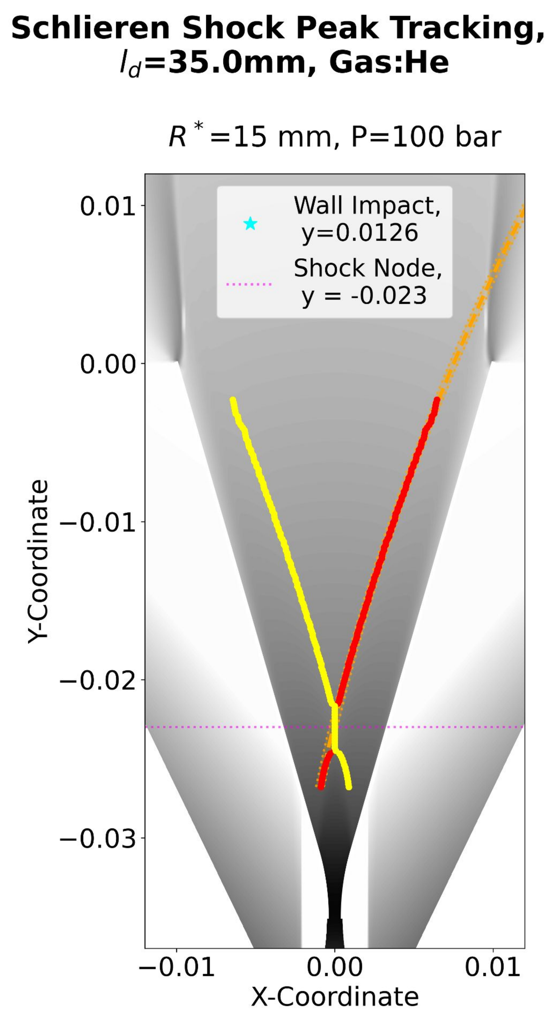


The Ansys Fluent CFD software can simulate this difference in gas structure.

We can see the results in the density profiles.

To achieve a nozzle that produces a smooth profile for both gas types we must mitigate the actual cause of the shocks: The throat.

Throat Curvature

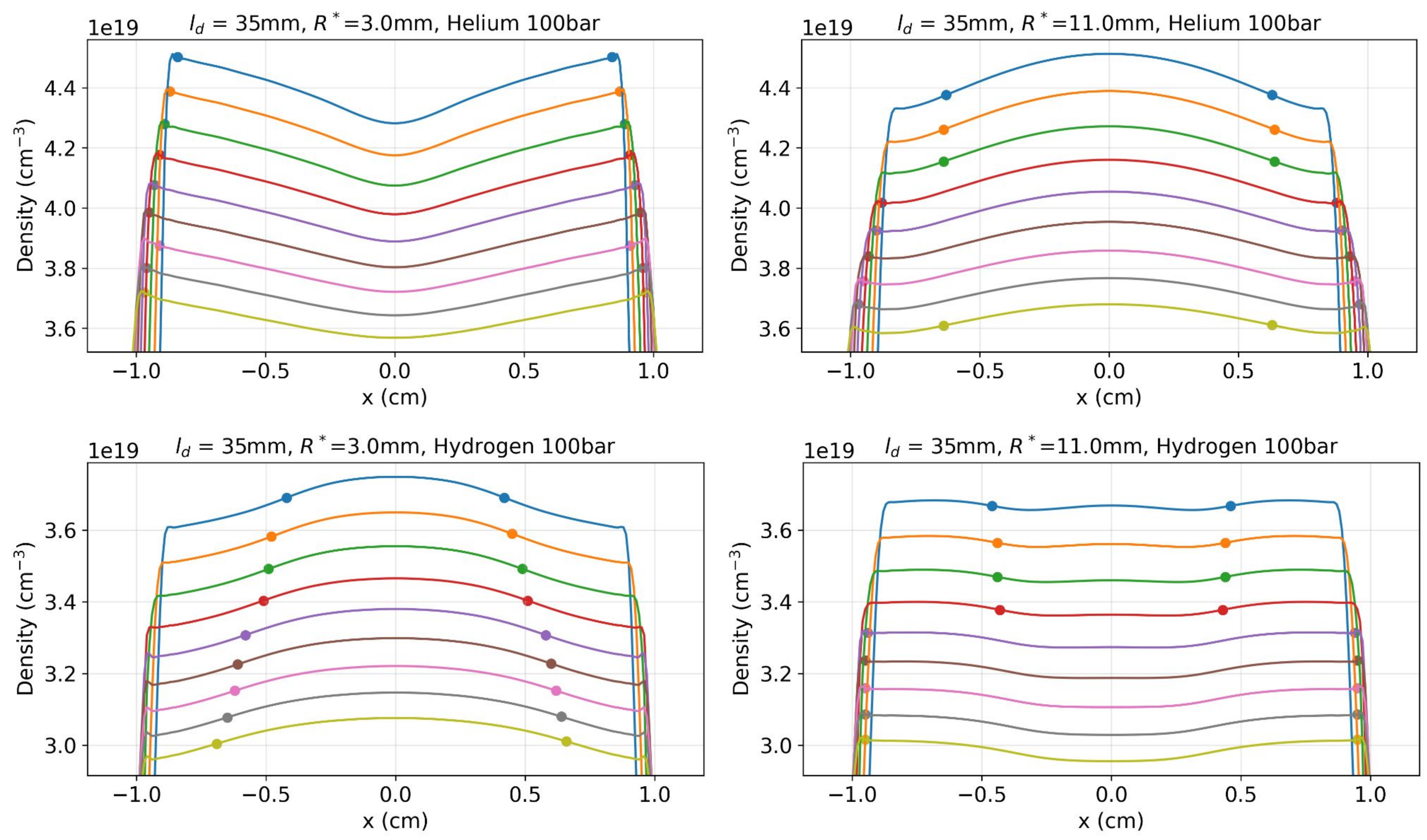


Adding throat curvature has two effects:

- **The shocks are softened.**
- **The shock trajectory is changed.**

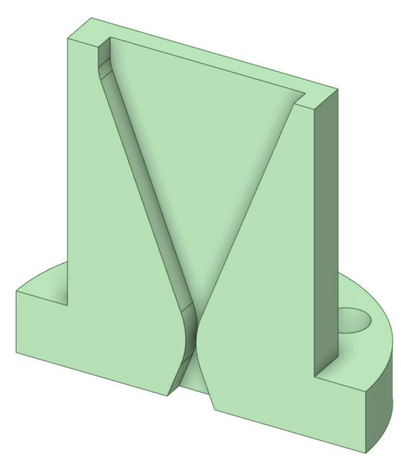
This allows us to aim the shocks to miss the lip and produce a dome, aim them to converge and produce a dip or aim them anywhere in between for a flatter plateau.

We can find a curvature for a particular nozzle geometry to allow both gas types to perform similarly and so produce gas interchangeable nozzles.

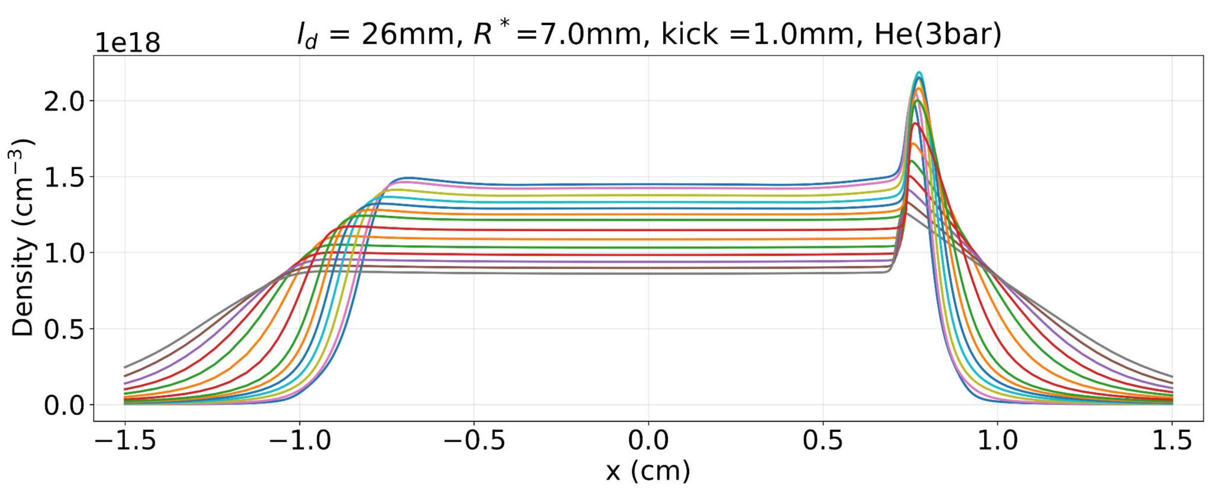


Advanced nozzle design

Using throat curvature we guarantee a flat plateau.
With a 'kicker' built into the nozzle a density peak can be directed by the nozzle. Taking advantage of a wider choice of nozzle angles we can direct the density peak to propagate perpendicular to the nozzle exit.



Plot shows density profiles each millimeter out to 20mm



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