lecture 27.10.2010

we had in the last week:

- few more remarks on cluster physics
- atomic physics: history
- Doppler-reduced spectroscopy
- preparation of atomic beams part I

today:

- preparation of atomic beams II: how to detect atoms, adjusting neutral atom energies, nozzle and skimmer shapes
- application of ultracold atom beams for isotope selective HFS spectroscopy

preparation of supersonic atomic beams
by adiabatic jet expansion

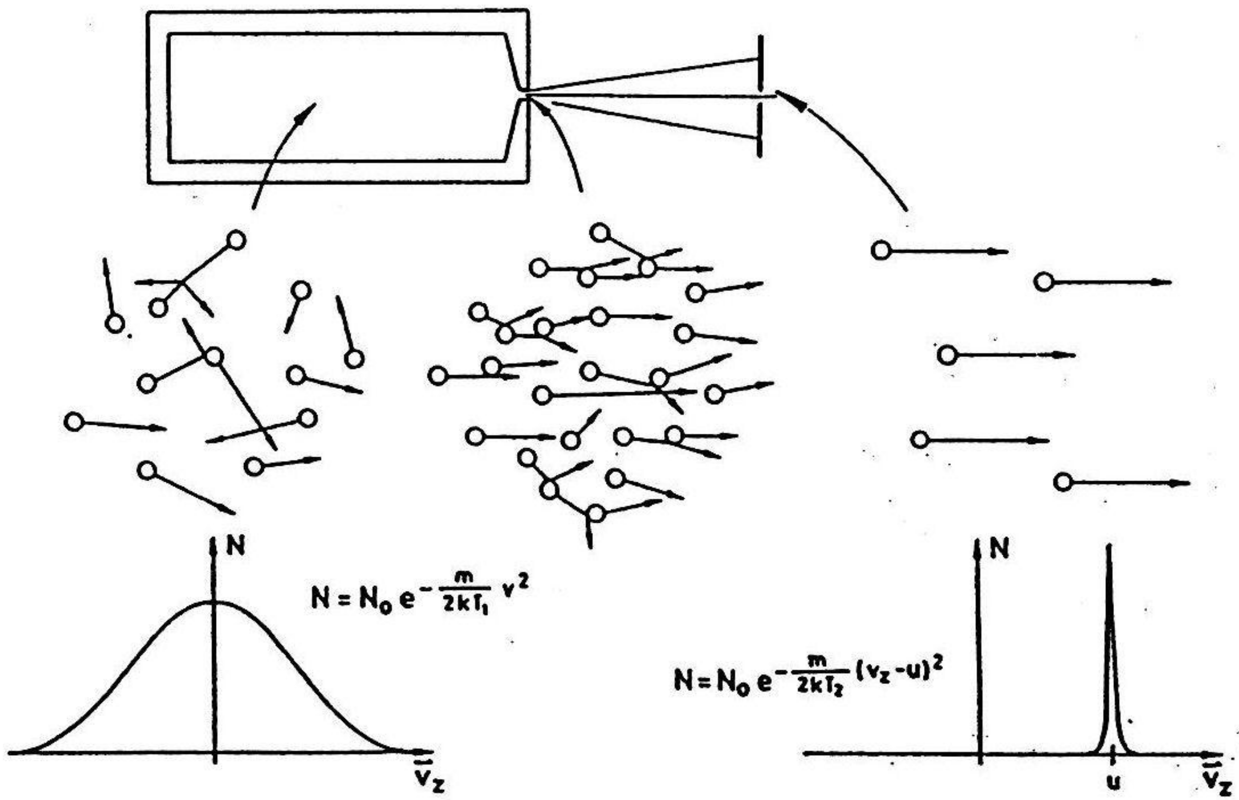


Fig. 8: Die mikroskopische Ursache für die Temperaturerniedrigung und Clusterbildung bei der adiabatischen Expansion [13]. Im Ausgangsbehälter herrscht vor der Expansion thermisches Gleichgewicht. Die ungerichtete Geschwindigkeitsverteilung der Teilchen ist durch die Maxwellverteilung bestimmt. Bei der Expansion des Gases durch eine Düse kommt es durch Stöße mit den anderen Gaspartikeln zur Abnahme der inneren Energie zu Gunsten der Expansionsgeschwindigkeit u. Die Relativgeschwindigkeit im kalten Molekularstrahl nimmt stark ab, wodurch die "kalten" Atome zu Clustern zusammenlagern.

early experiments

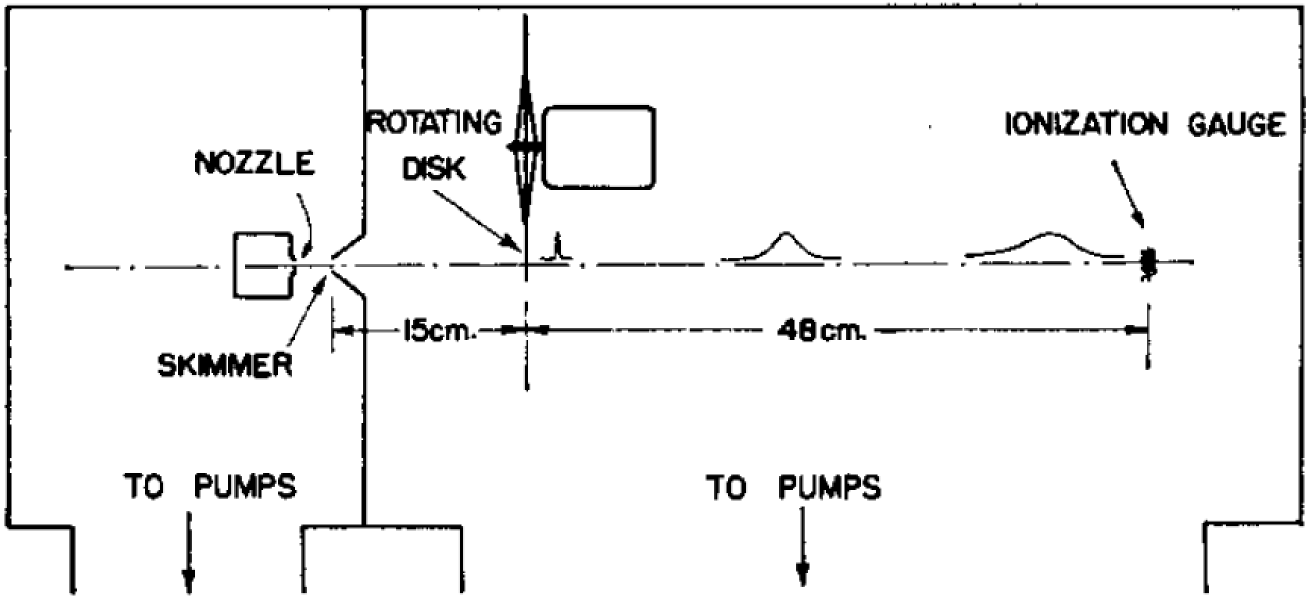


FIG. 3. Apparatus for determination of axial velocity distributions.

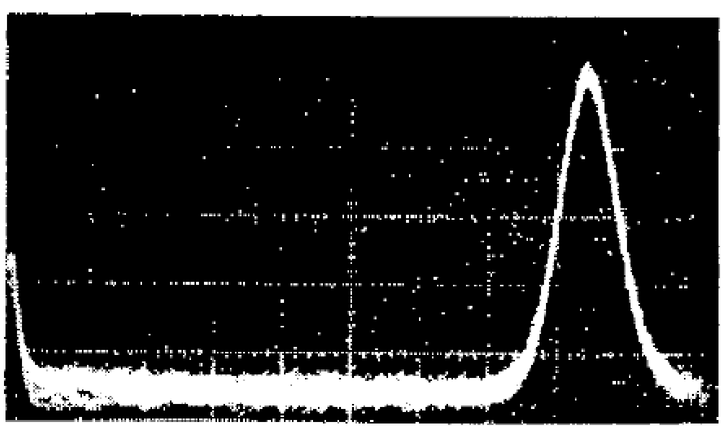
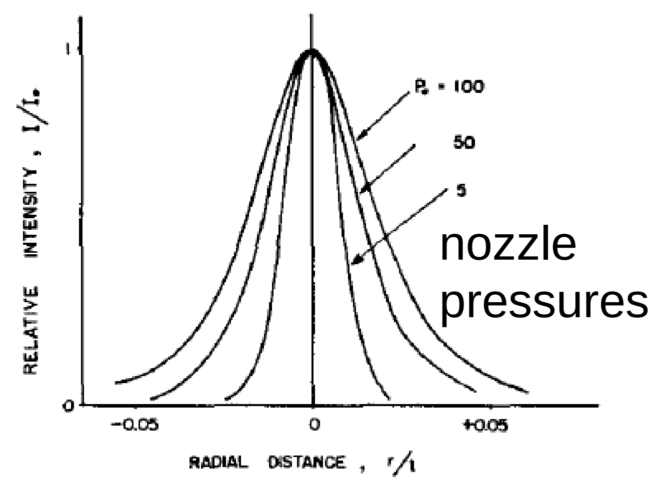
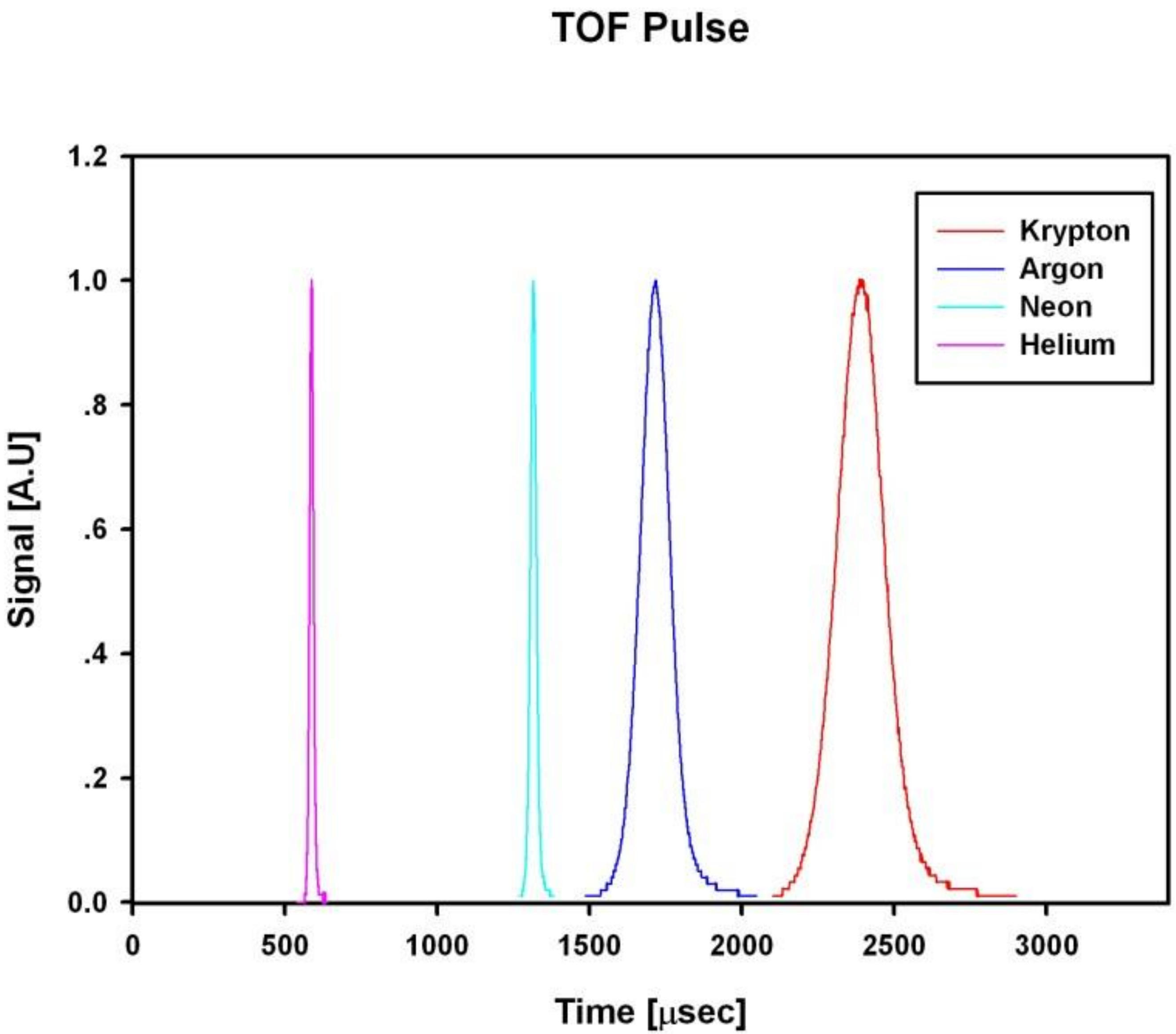


FIG. 5. A typical oscillogram for an argon beam with a velocity distribution corresponding to $M = 16$.



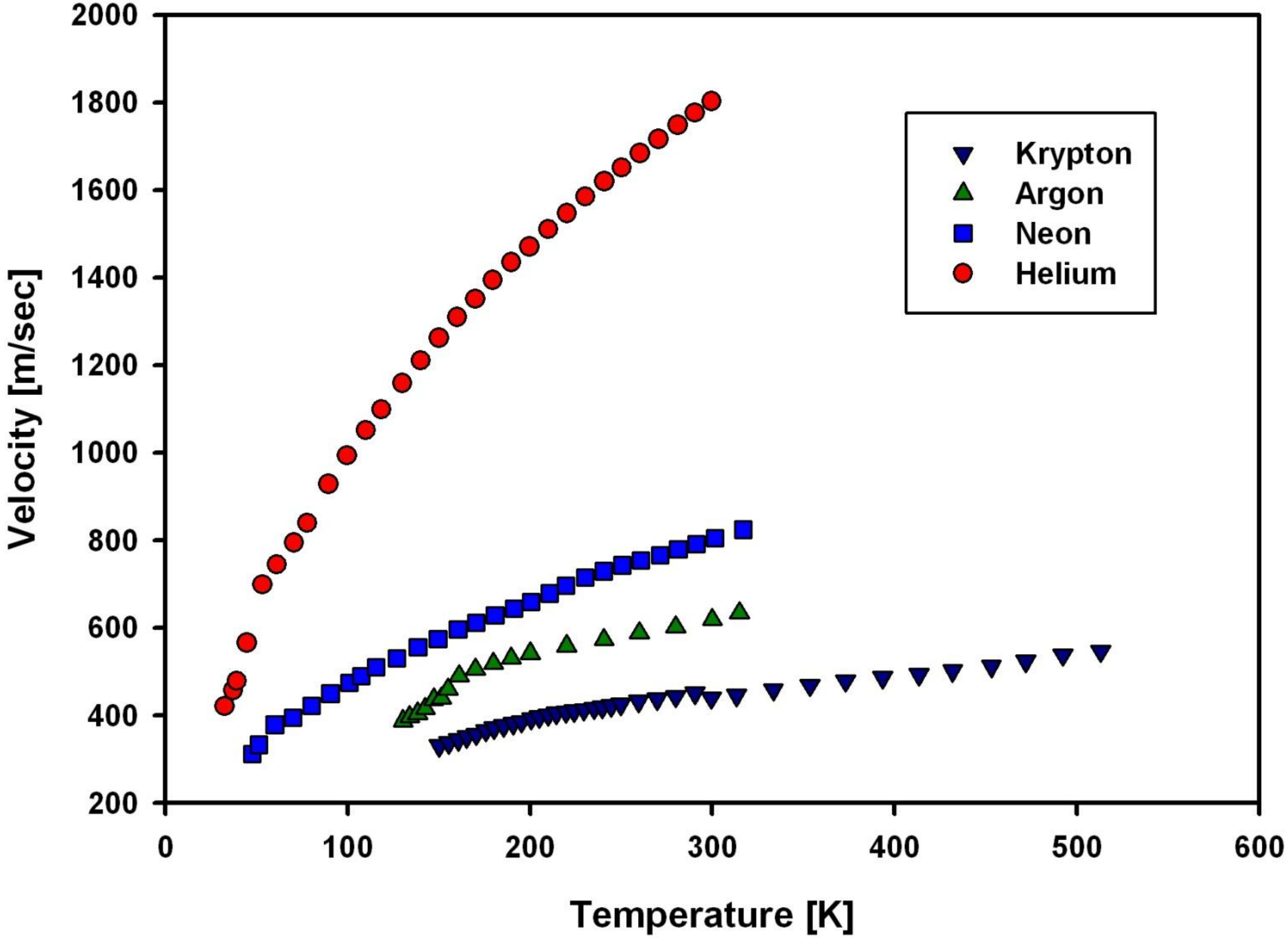
Andersen and Fenn, The physics of fluids 8 (1965) 780

arrival time distribution after ~1 meter flight.



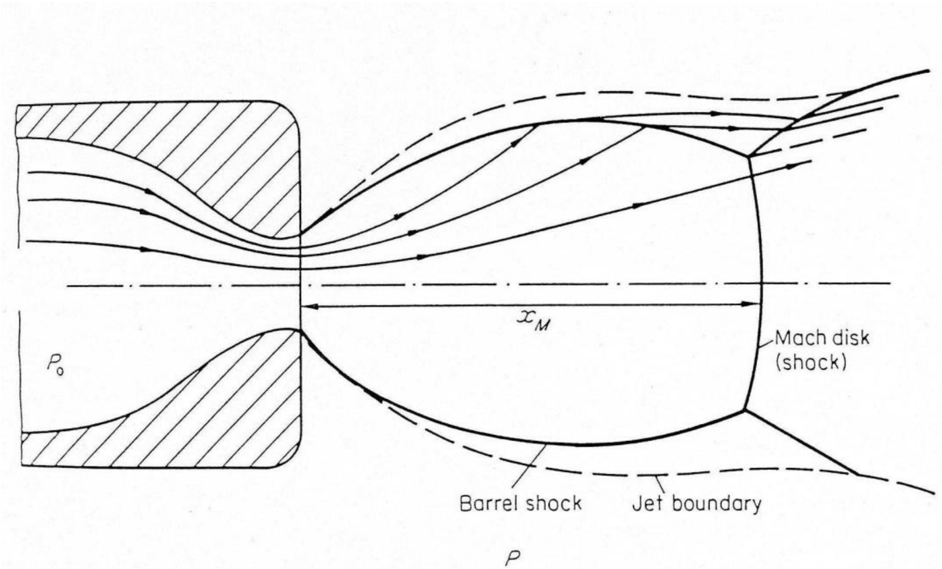
temperature dependence of jet velocity

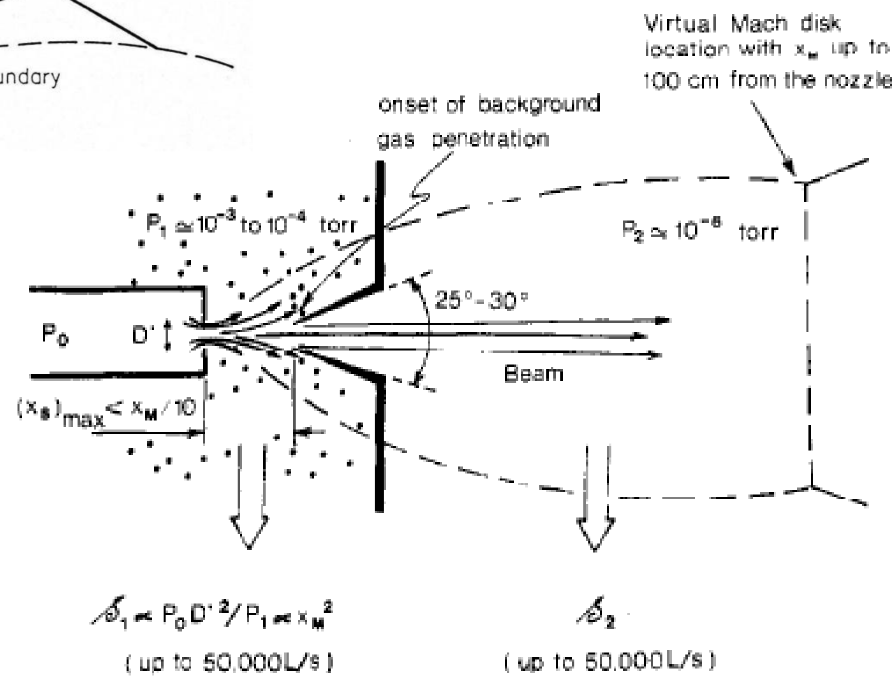
J. Chem. Phys. 118, (19),8690 (2003)



this is THE method to adjust the energy of neutral atoms!

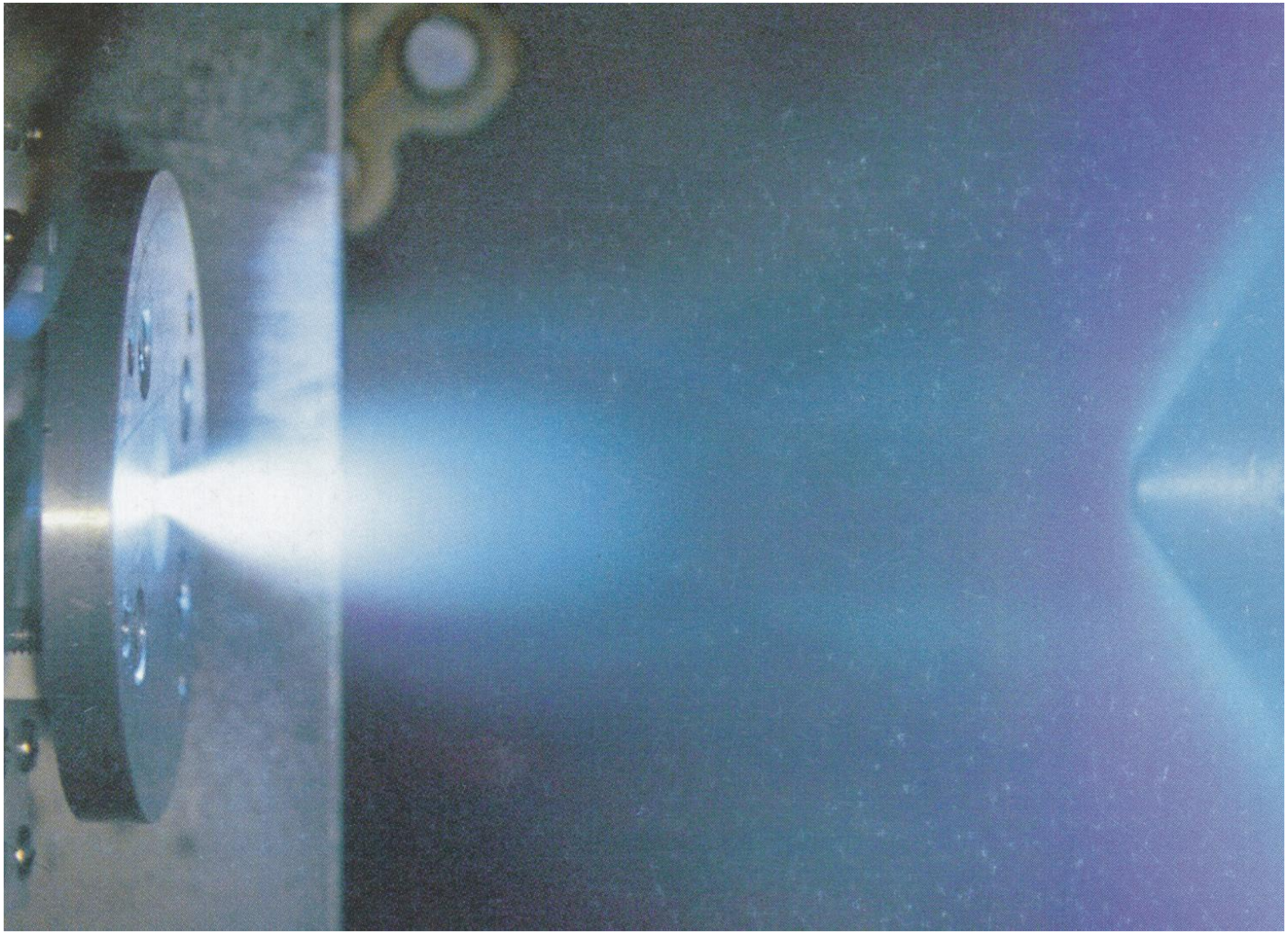
supersonic jet expansion





own experiment: expansion from the cluster source

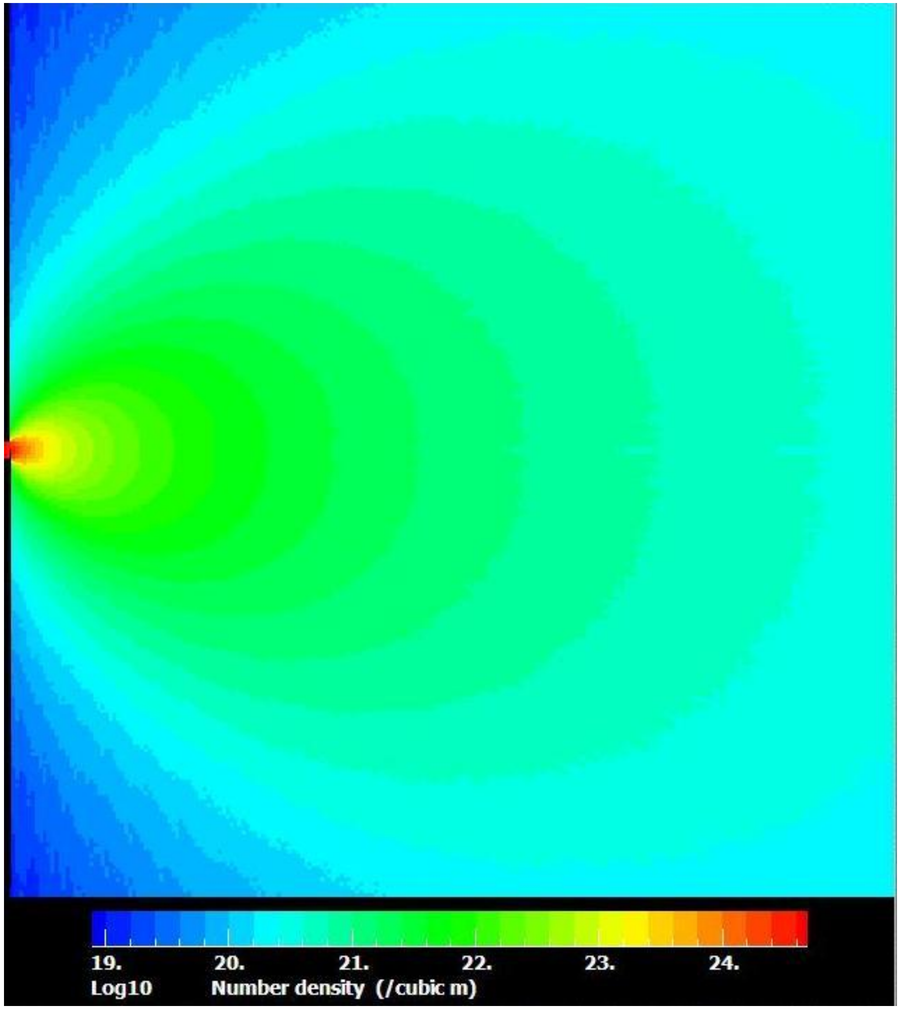
ACIS: arc cluster ion source

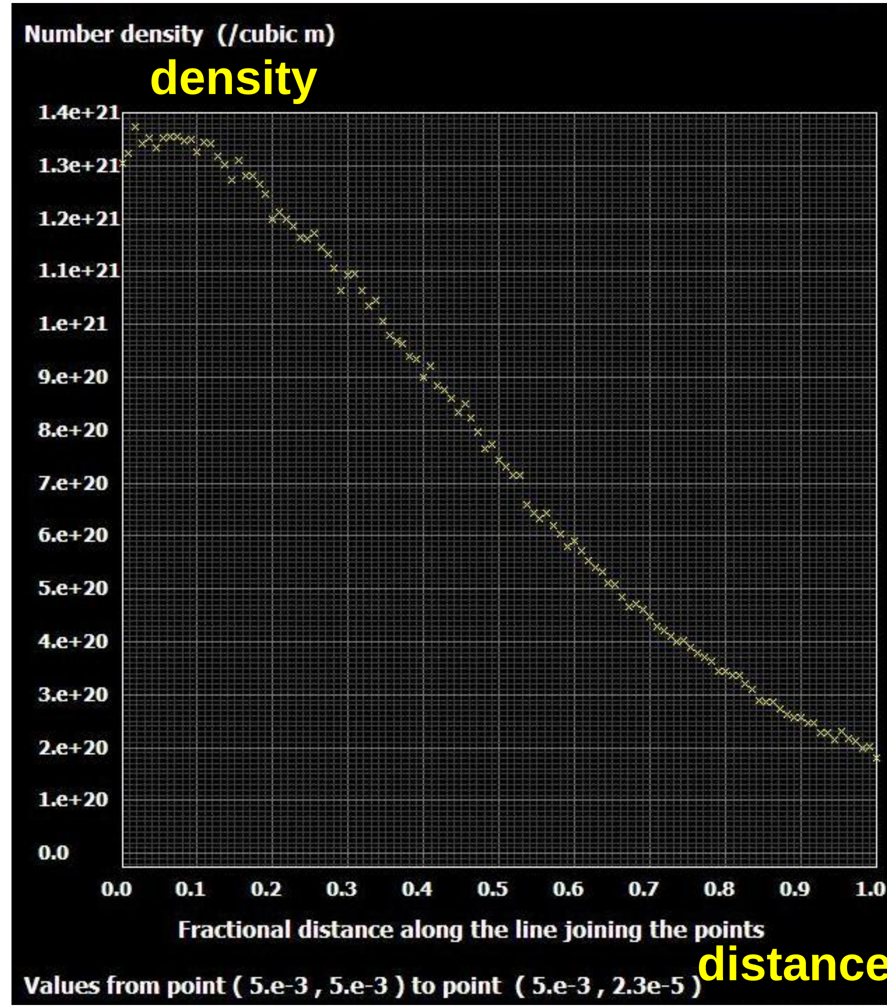


more simulations: sonic nozzle beam

Monte Carlo method (DSMC)

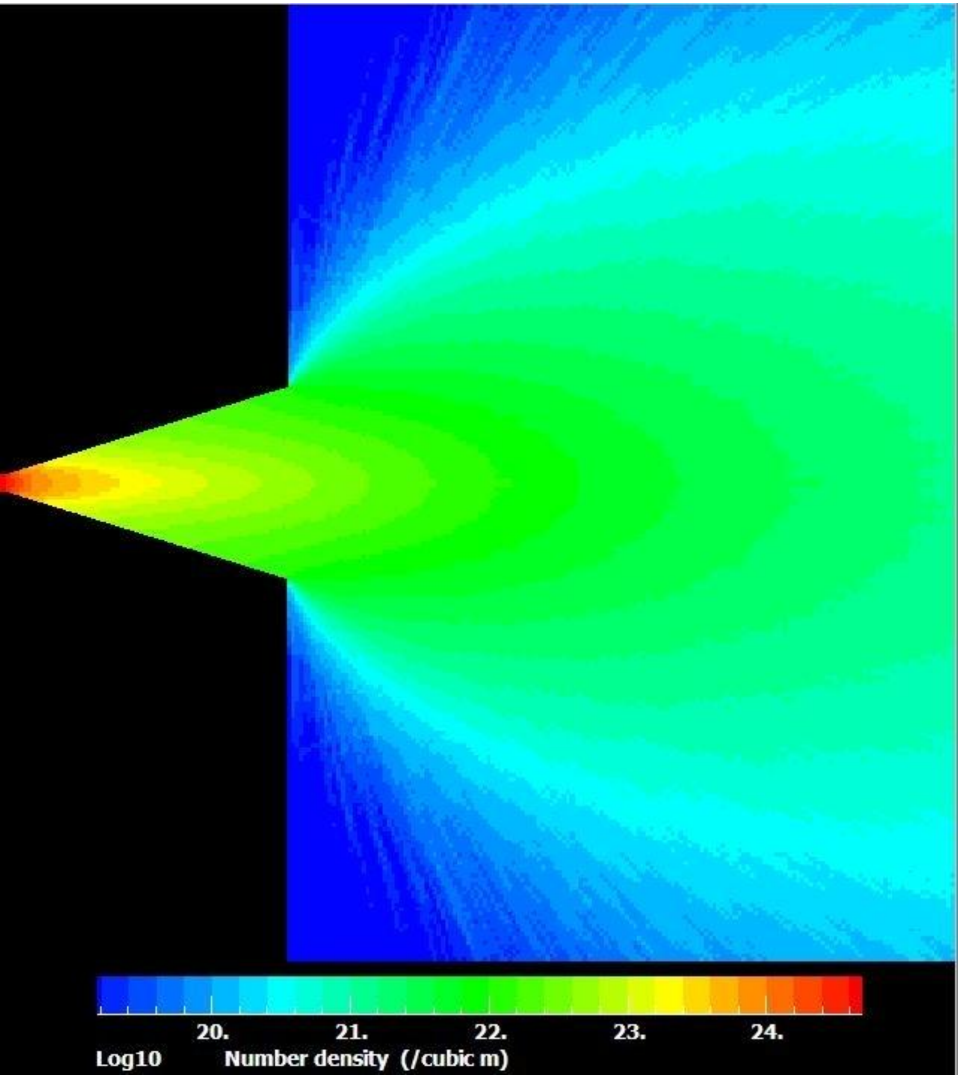
Program developed by Dr. Graham Bird and is free http://www.gab.com.au/

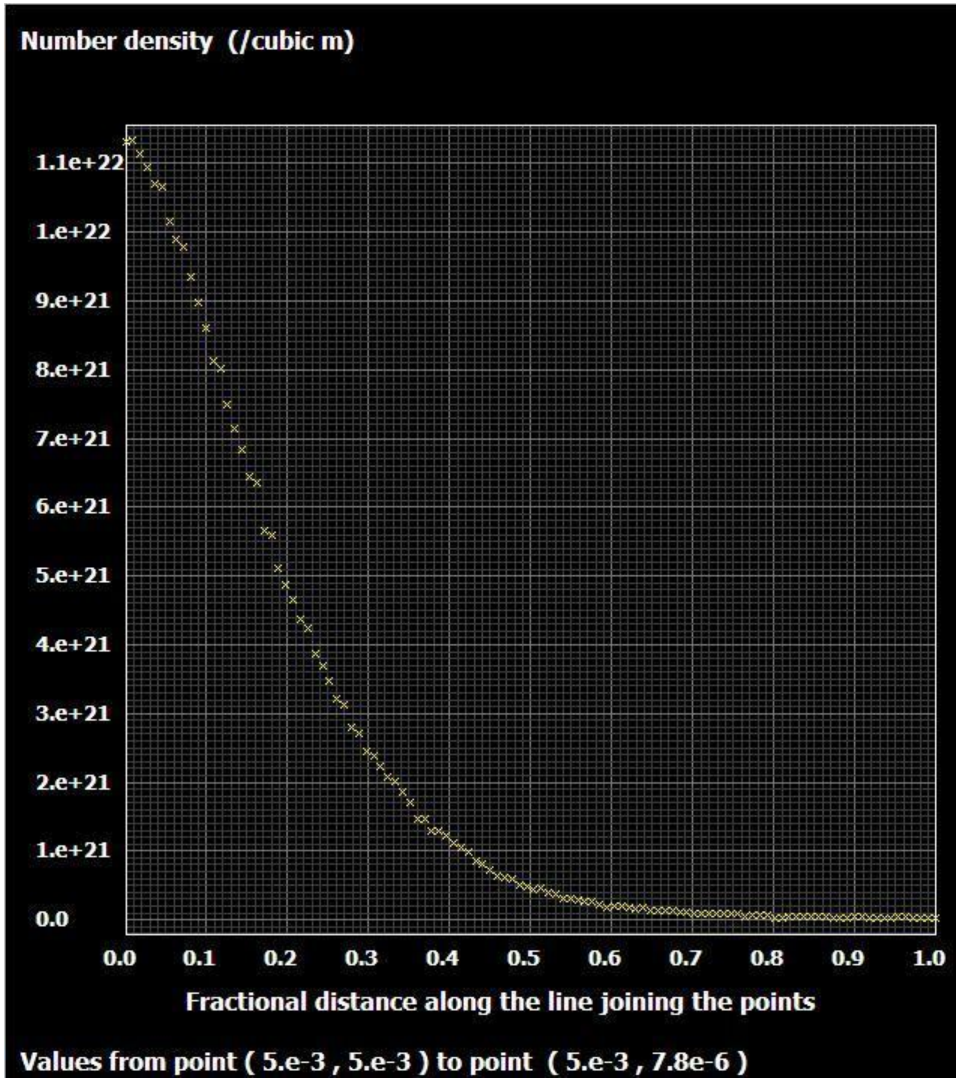




wide beam (55^0 FWHM); low on axis intensity

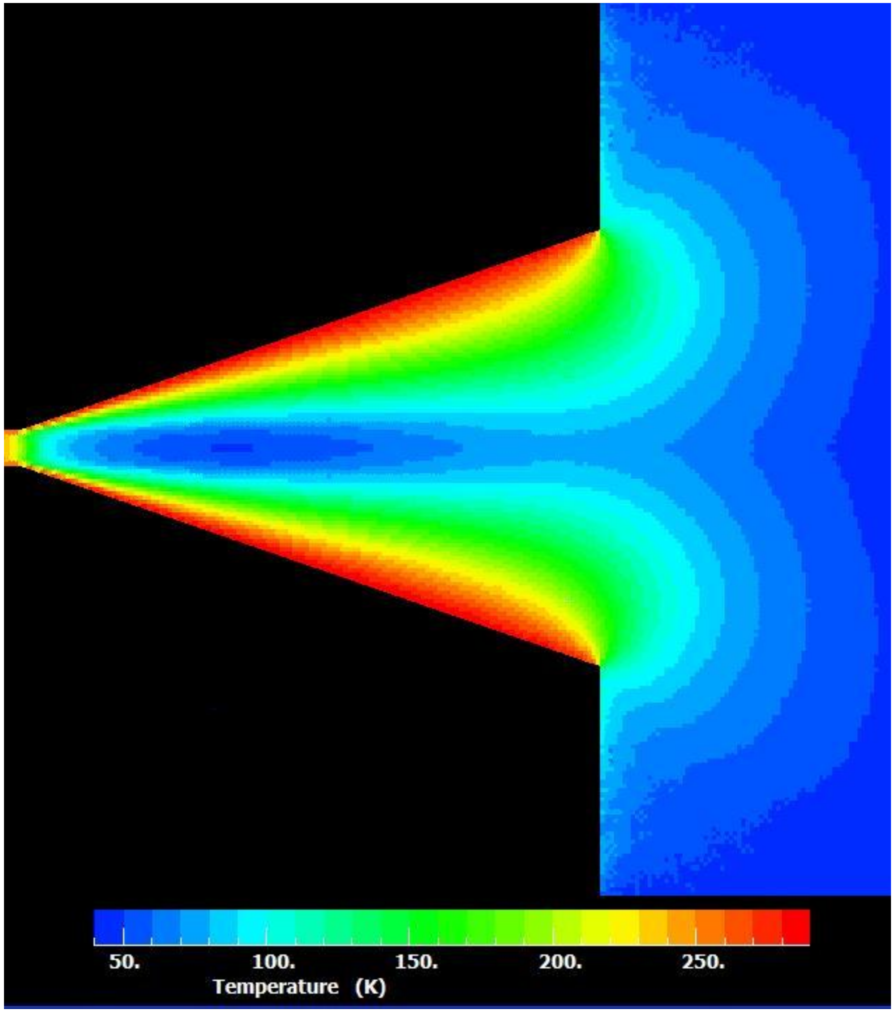
40^0 Conical Nozzle Simulation

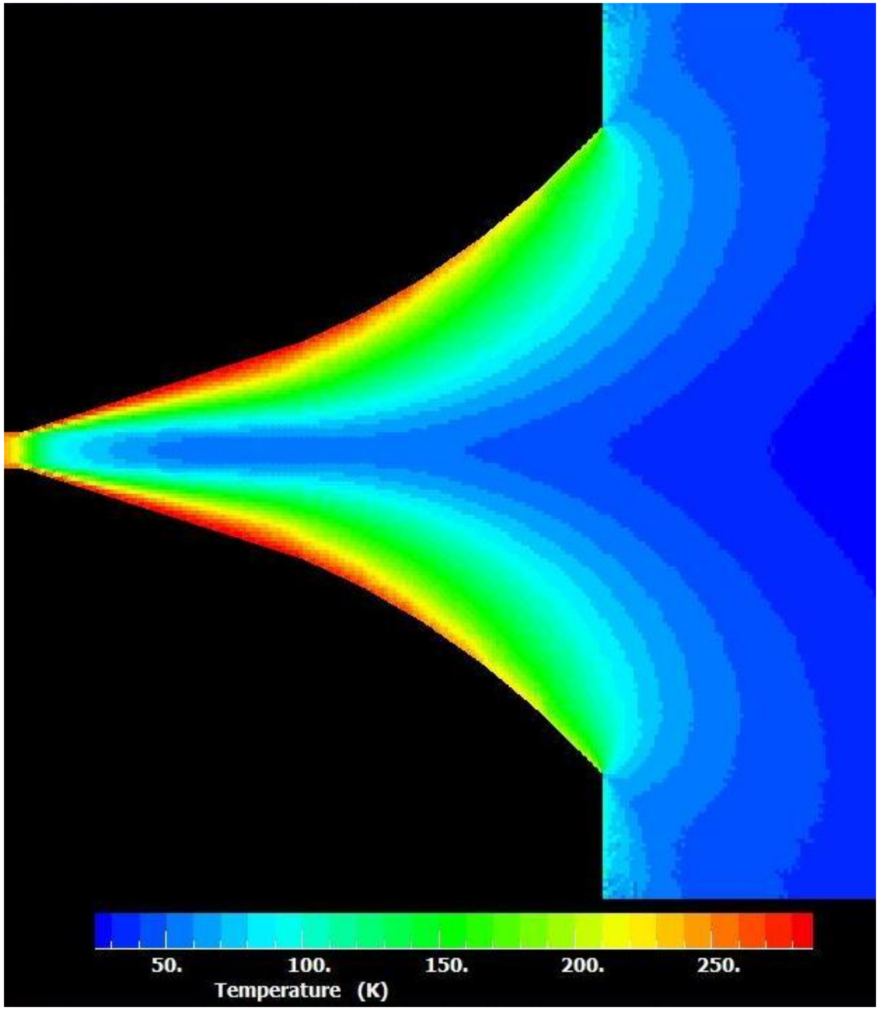




narrow beam (20^0 FWHM); higher on axis beam intensity (x8 over sonic nozzle)

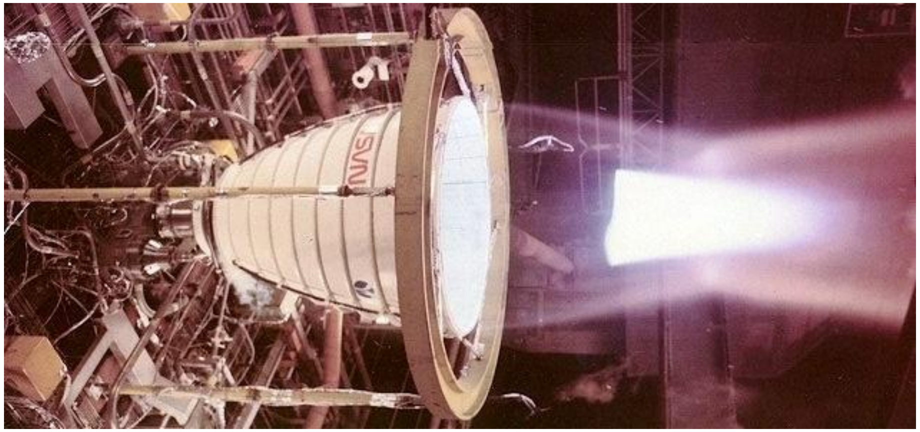
temperatures: conical and trumpet shaped nozzles

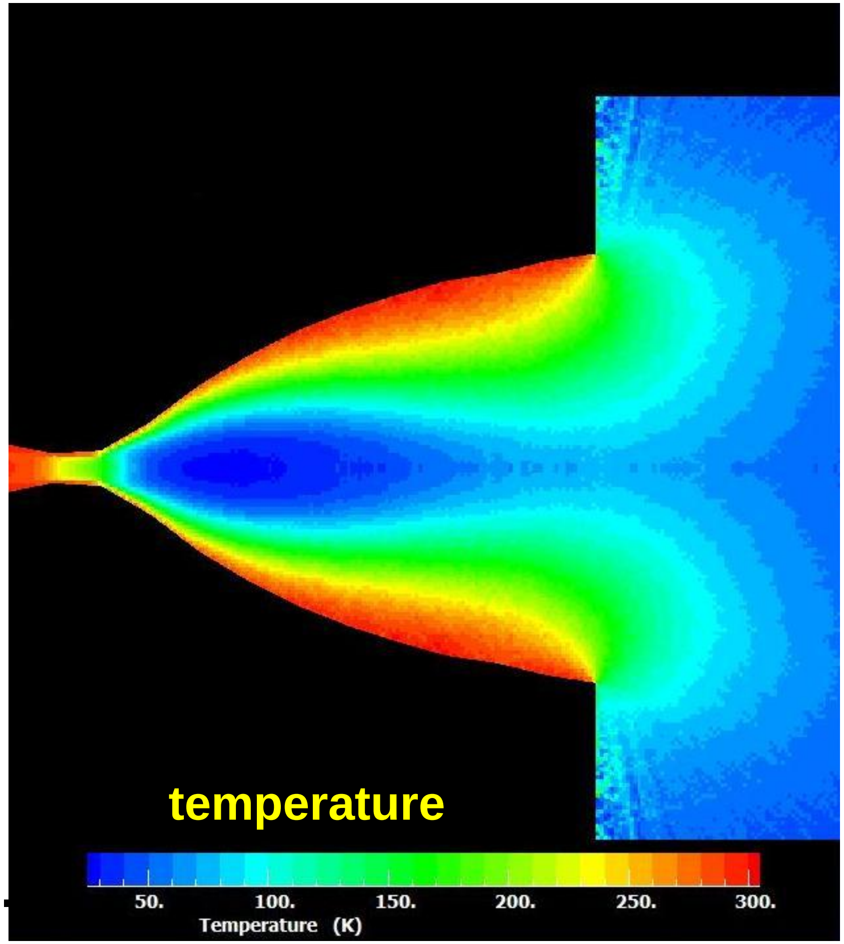




Low temperature achieved where the jet is at high density; important for clustering

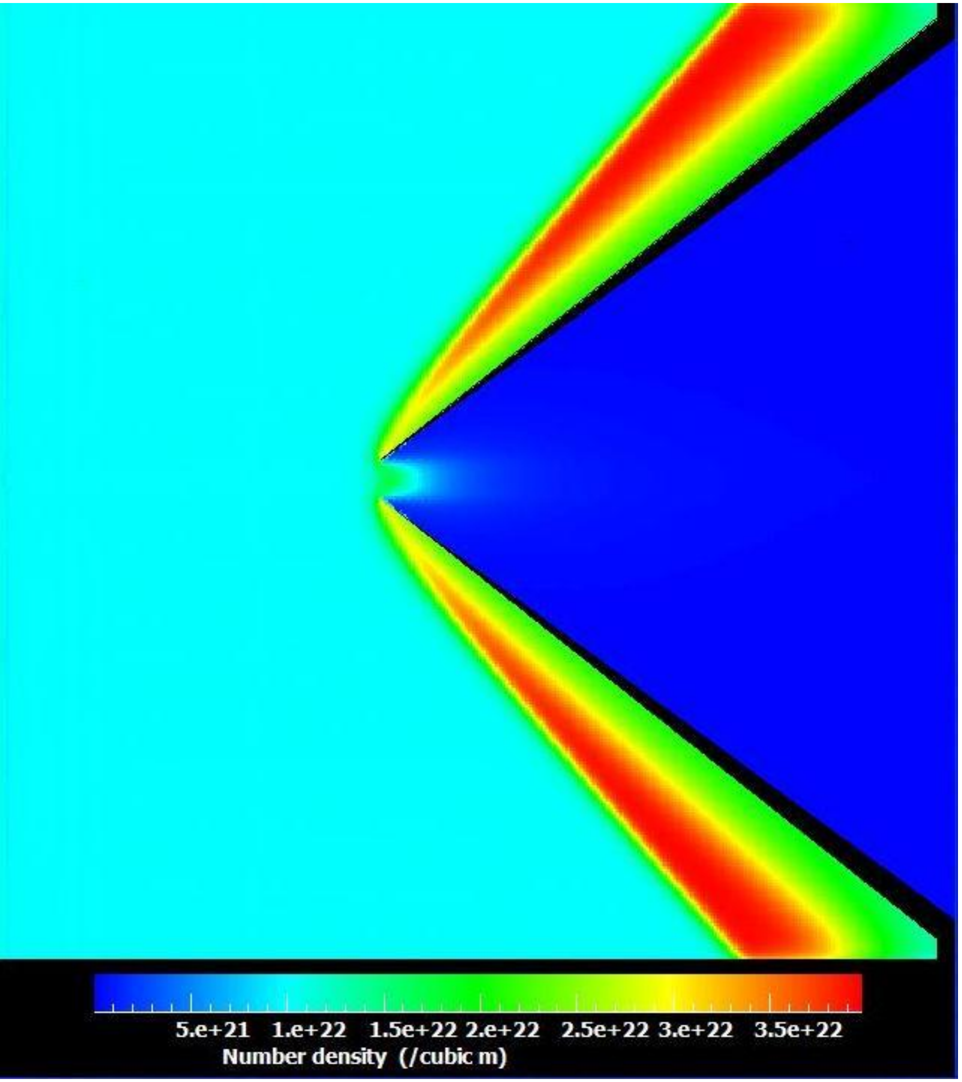
De Lavalle (or Bell) Nozzle

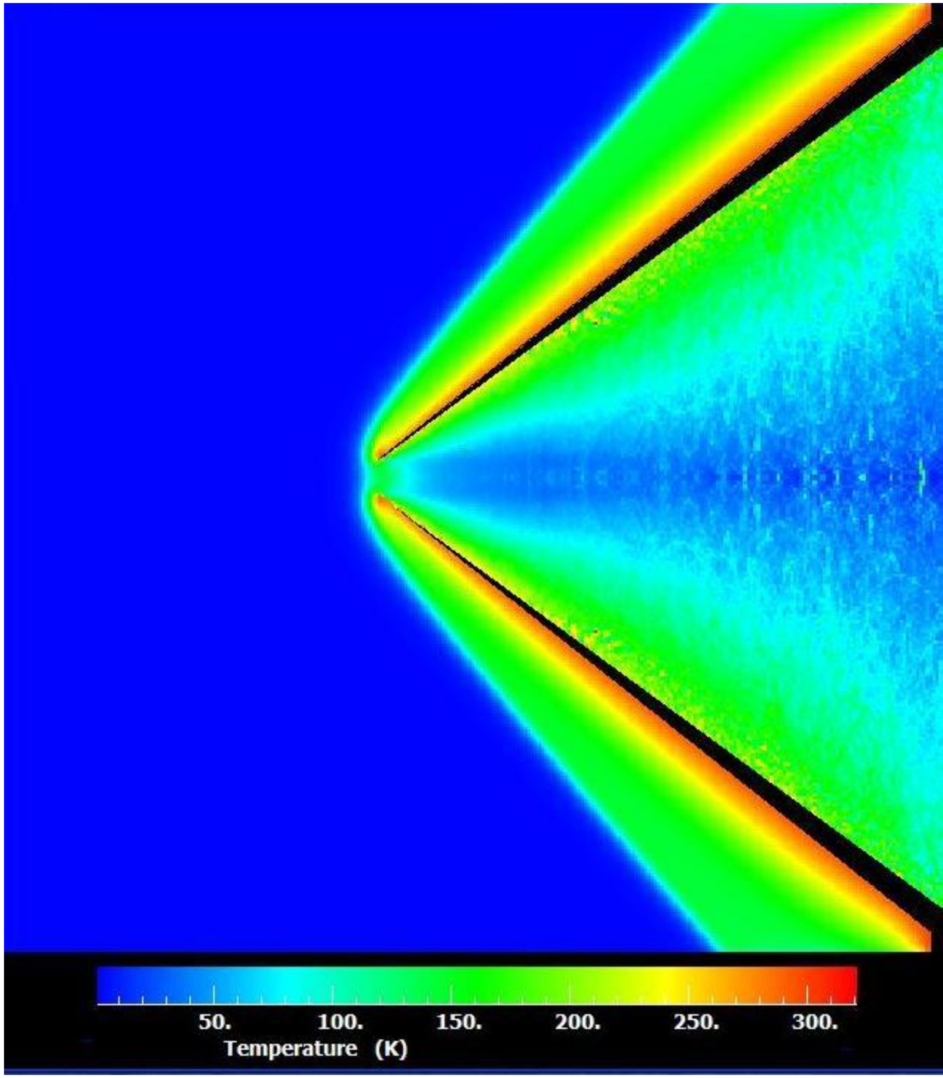




1. **Designed for Maximum Thrust.**
2. **Exit Temperature is quite high.**
3. **A bad source for supersonic beams.**

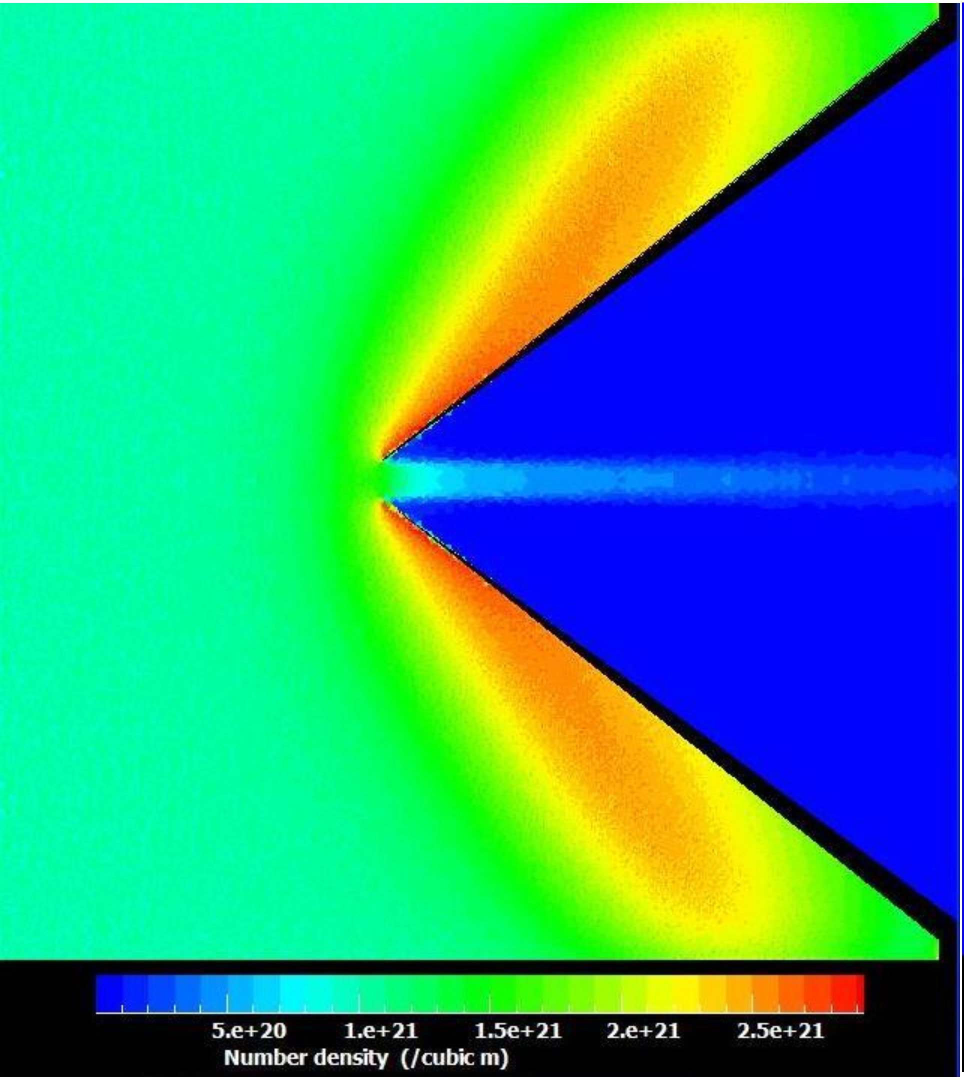
skimmers: Campargue type at low intensity beams

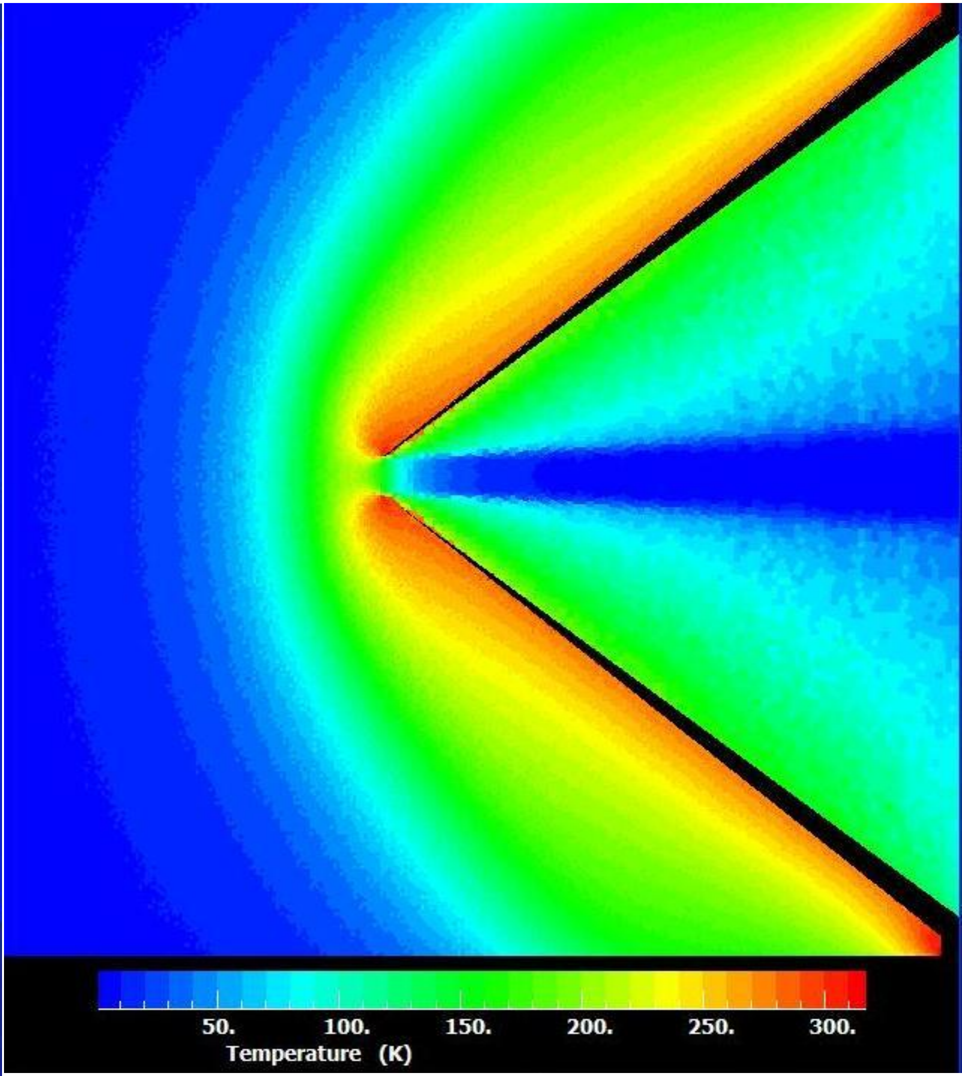




density **temperature**

Campargue type skimmer in high density beams



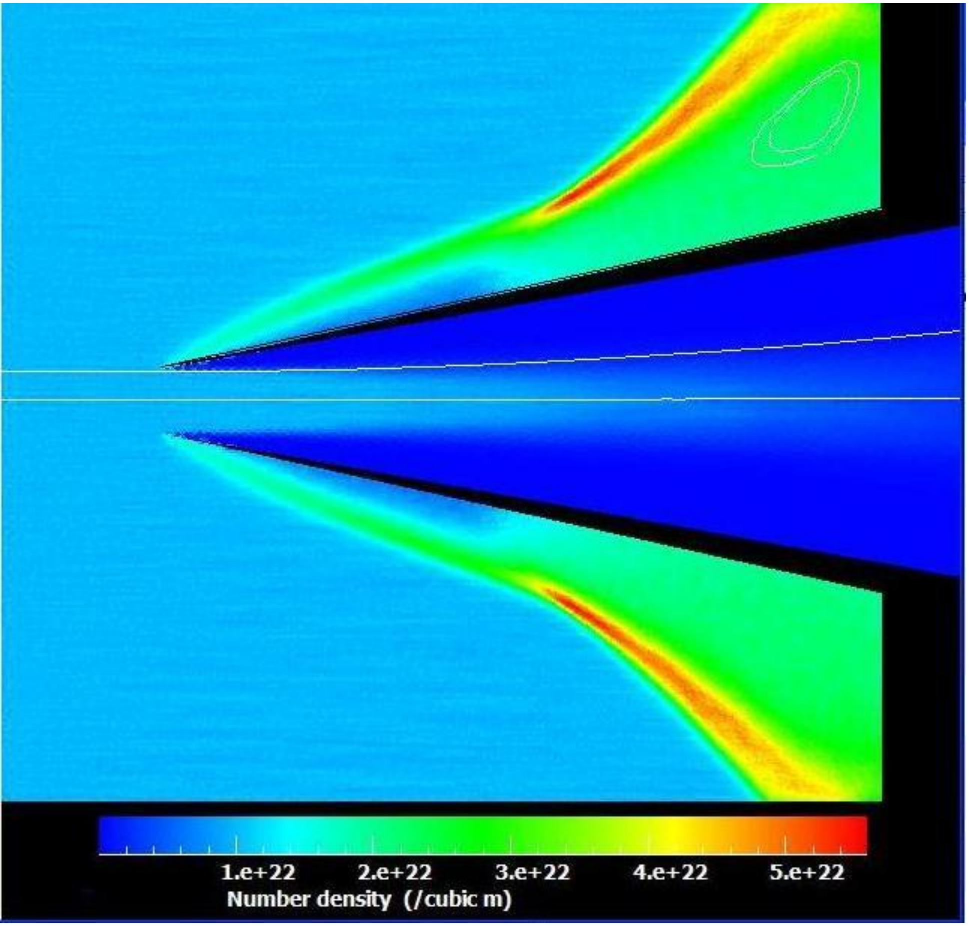


density

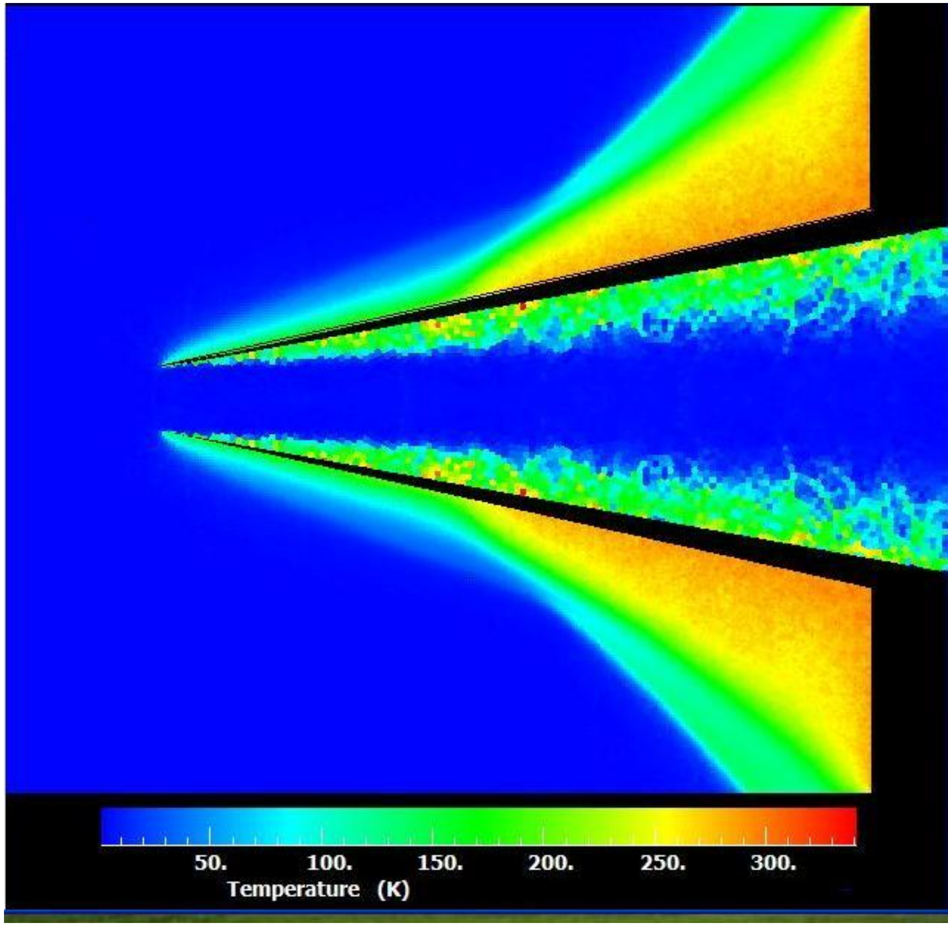
temperature

long conical skimmer at high beam intensity

large entrance hole, 25^0 full angle, 50 mm length.



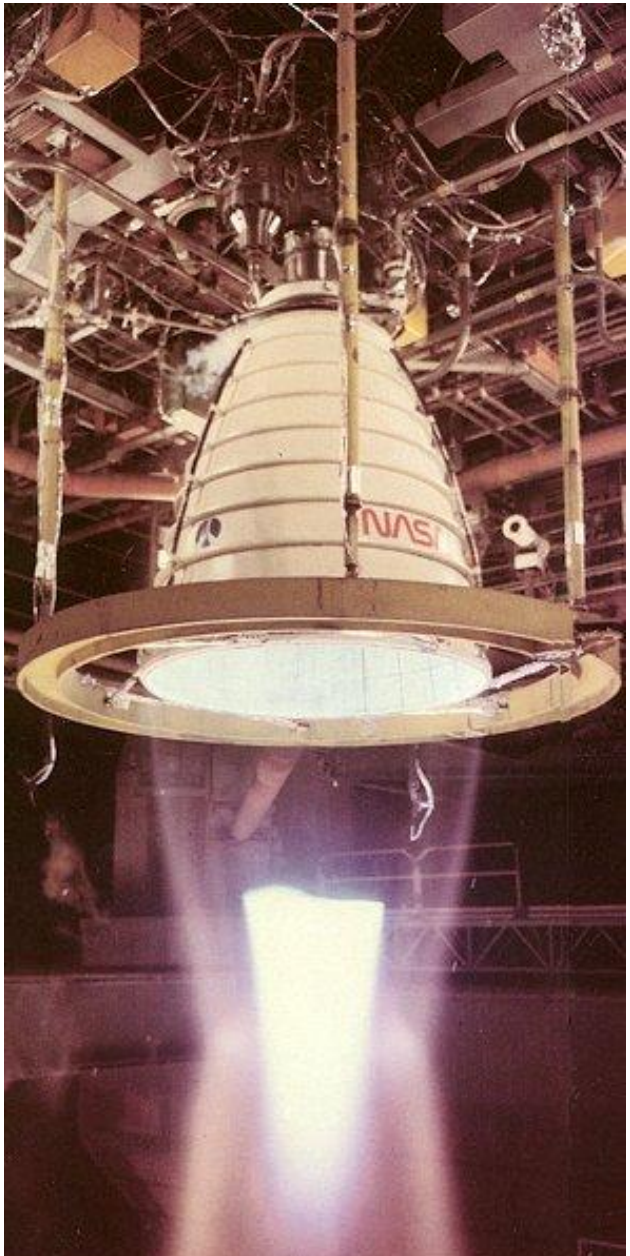
density

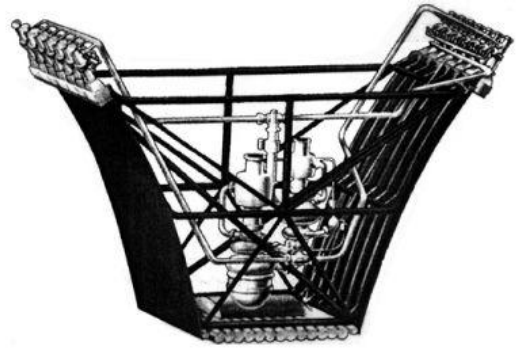


temperature

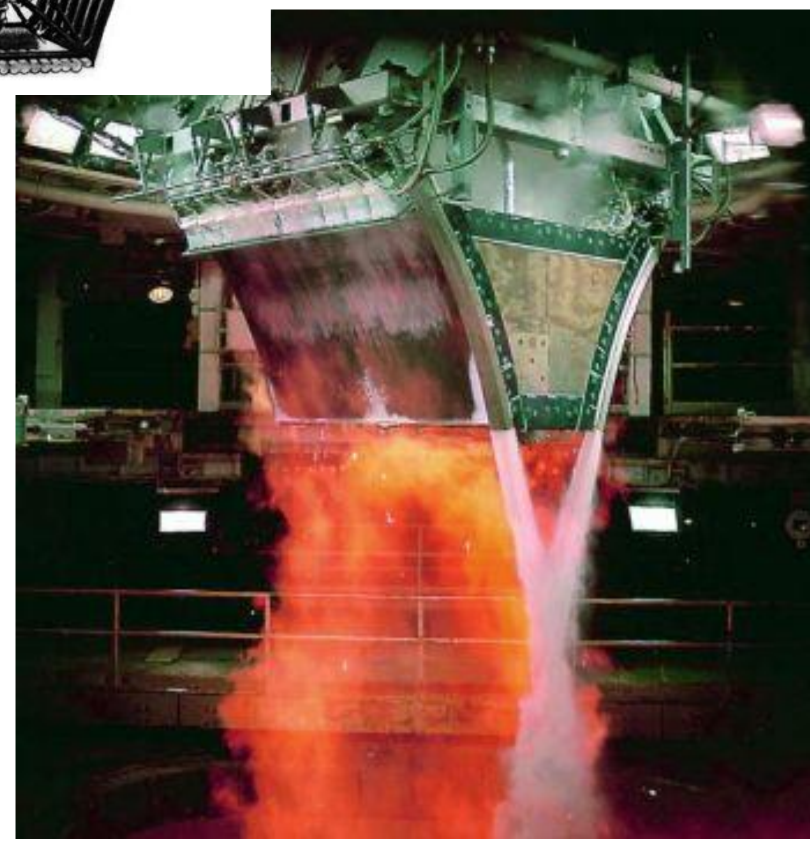
compare:

Mach disk, engine of Space Shuttle

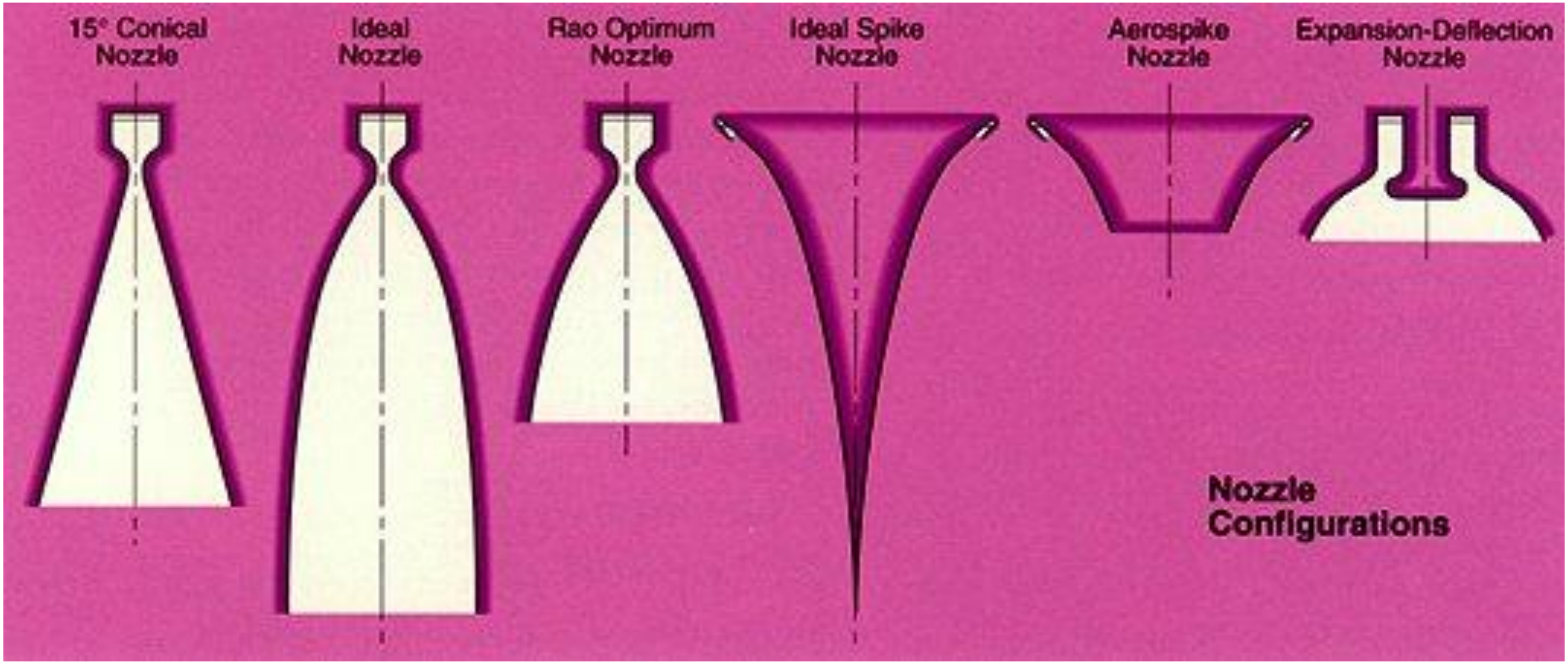




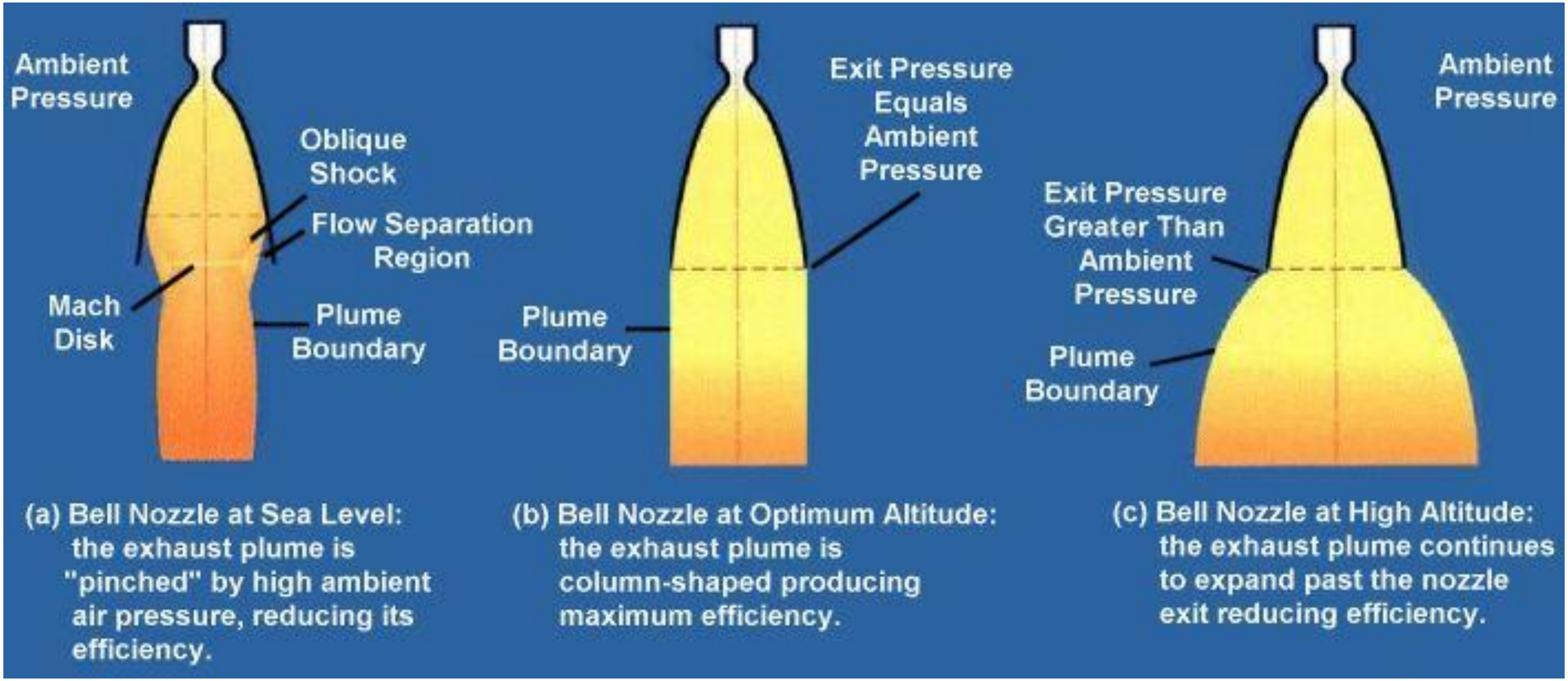
Aerospike nozzle



Types of rocket nozzles



performance depends on background pressure



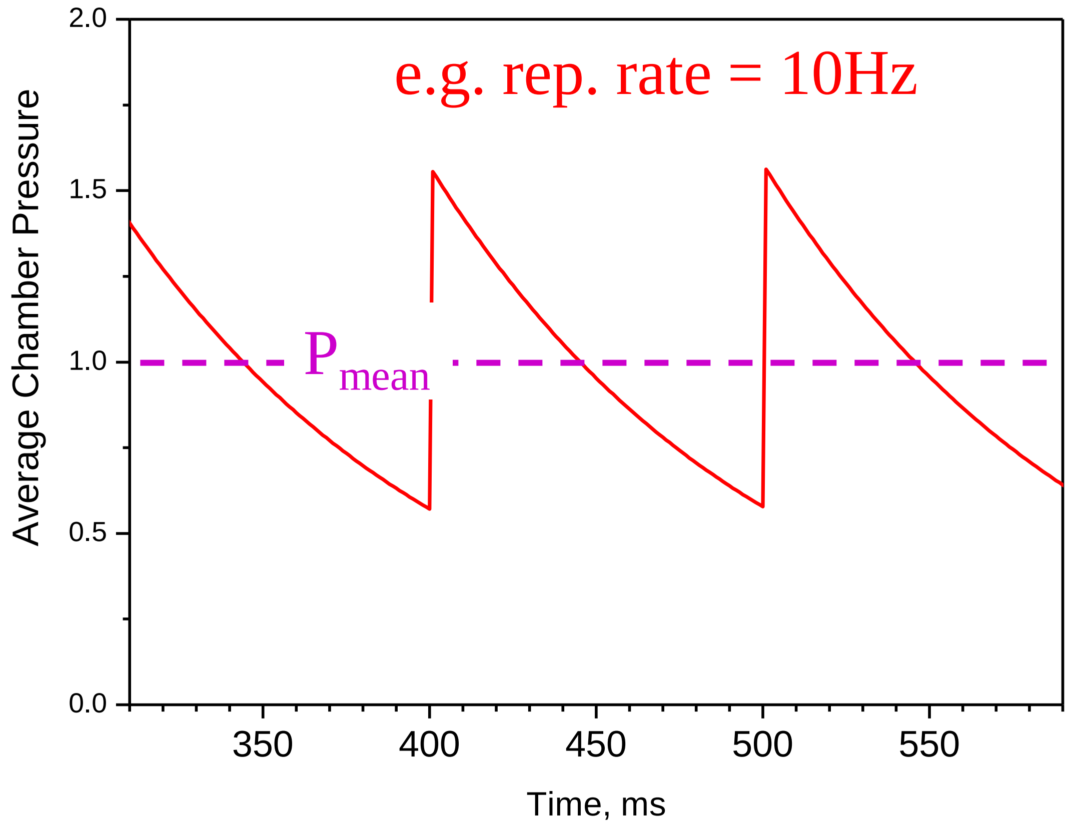
► we see: nozzle expansions are important on large and small scales

Pulsed supersonic molecular beam sources

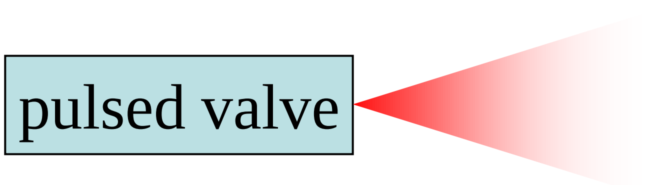
Pump out time $$\tau = \frac{V}{S}$$

V = Volume
S = Pumping Speed = S_2

Typical example, V=100 ℓ, S=1000 ℓ/s $\tau = 0.1s$

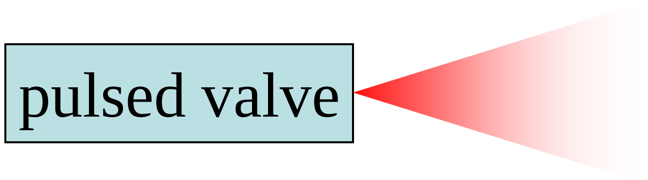


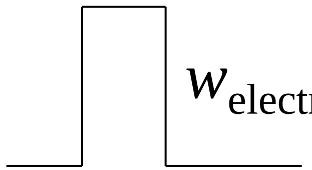
P_{jet}=P_1 >> P_2=$P_{chamber}$



practical pulsed beam source

delay and opening time issue



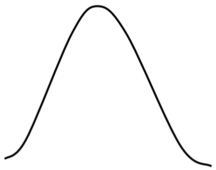


$w_{\text{electronic}}$

not equal to

not proportional to

may be anti-correlated with



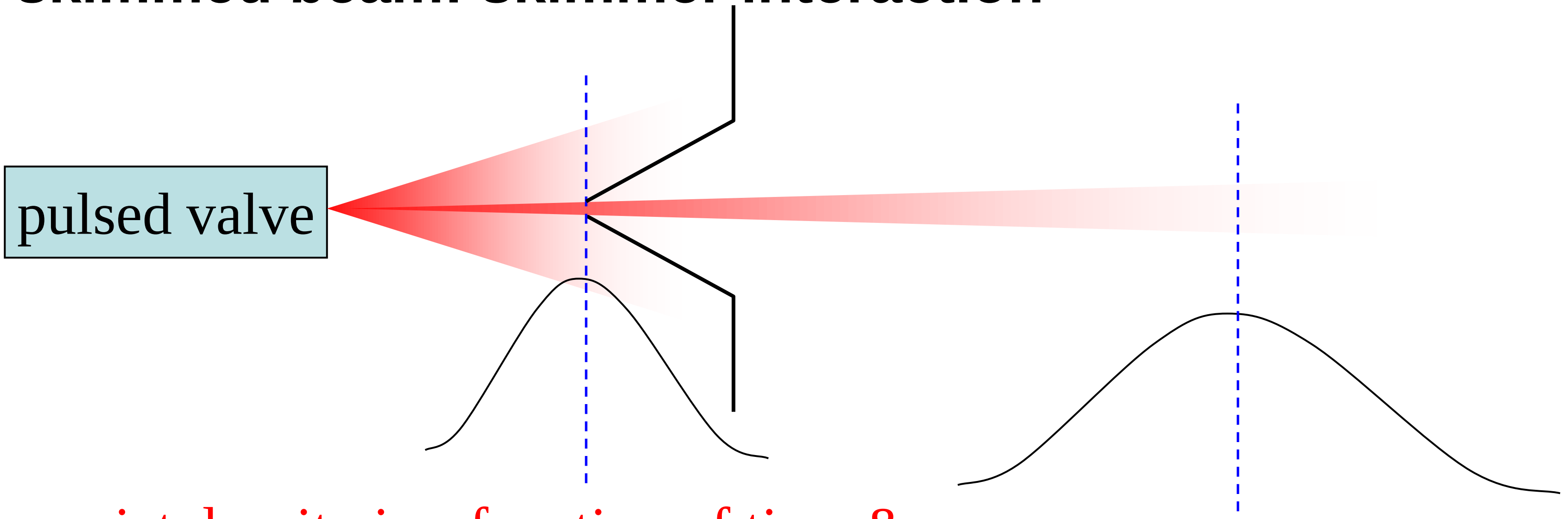
w_{gas}

large delay time due to mechanical delay

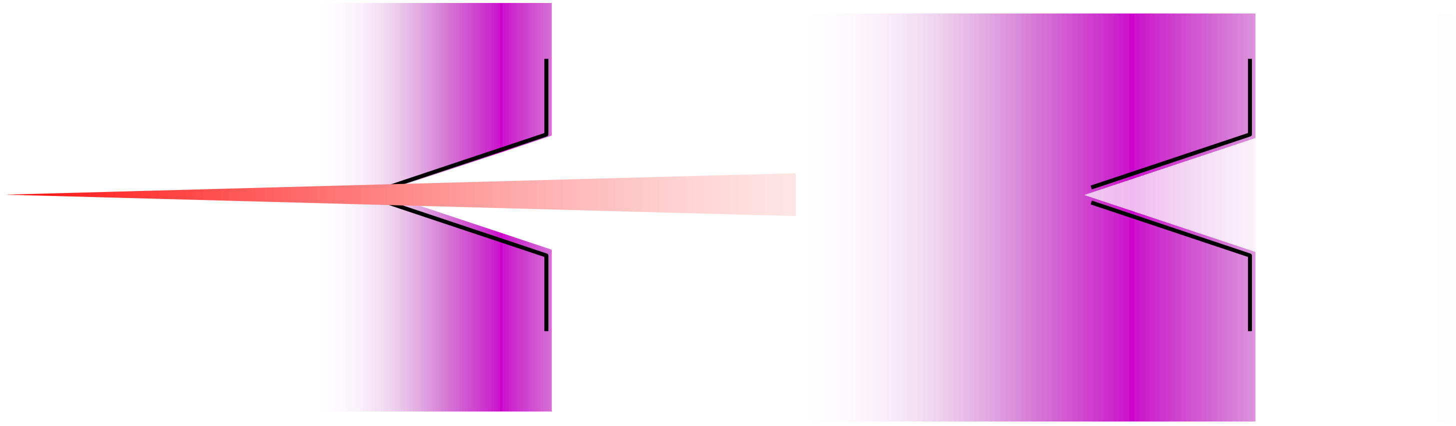
bigger w_{elect}
or higher power $\Rightarrow$ stronger force $\Rightarrow$ shorter delay time

possible smaller w_{gas}

skimmed beam: skimmer interaction

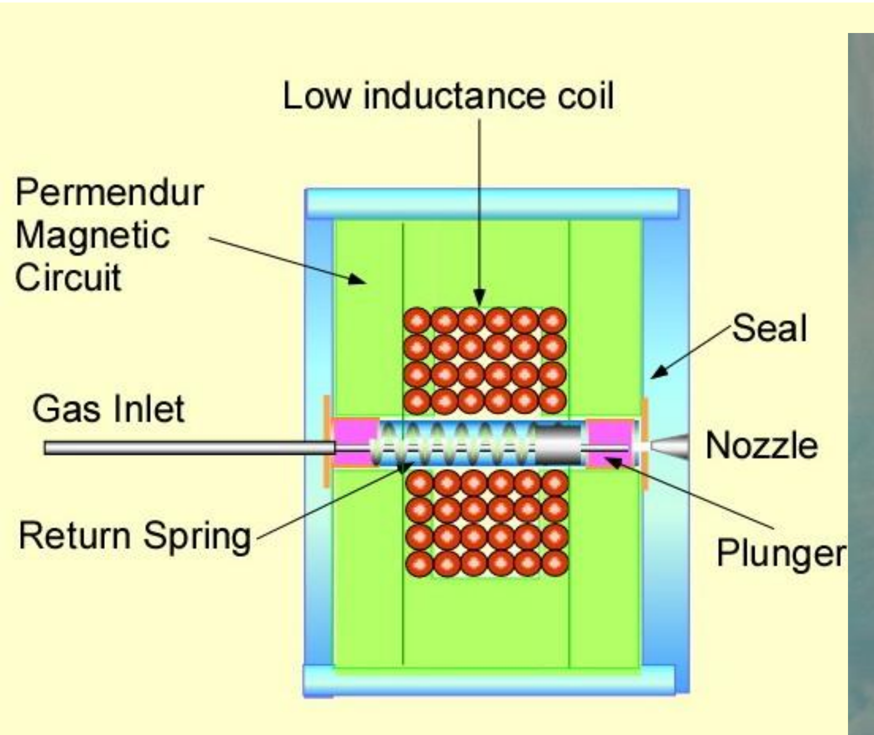


jet density is a function of time & space

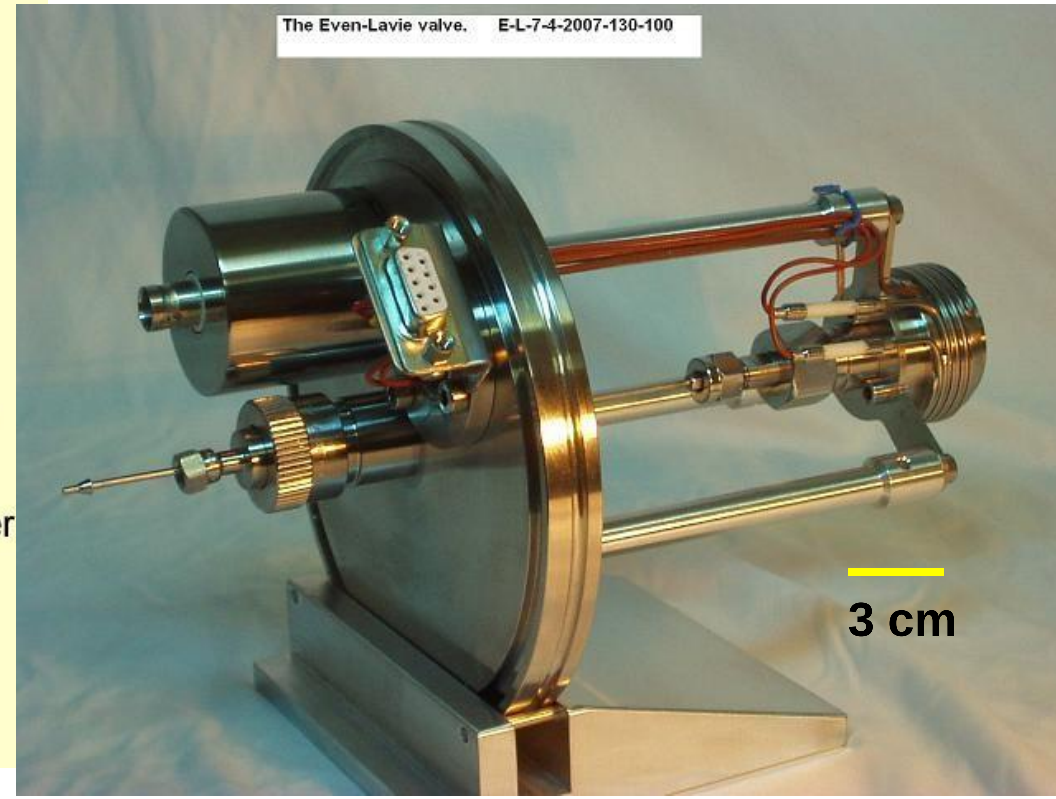


attenuation is also a function of time & space

structure of a pulsed valve: miniaturization is the key



20 microseconds, 100 Bars, 20-500K



example of atom beam application for fundamental questions

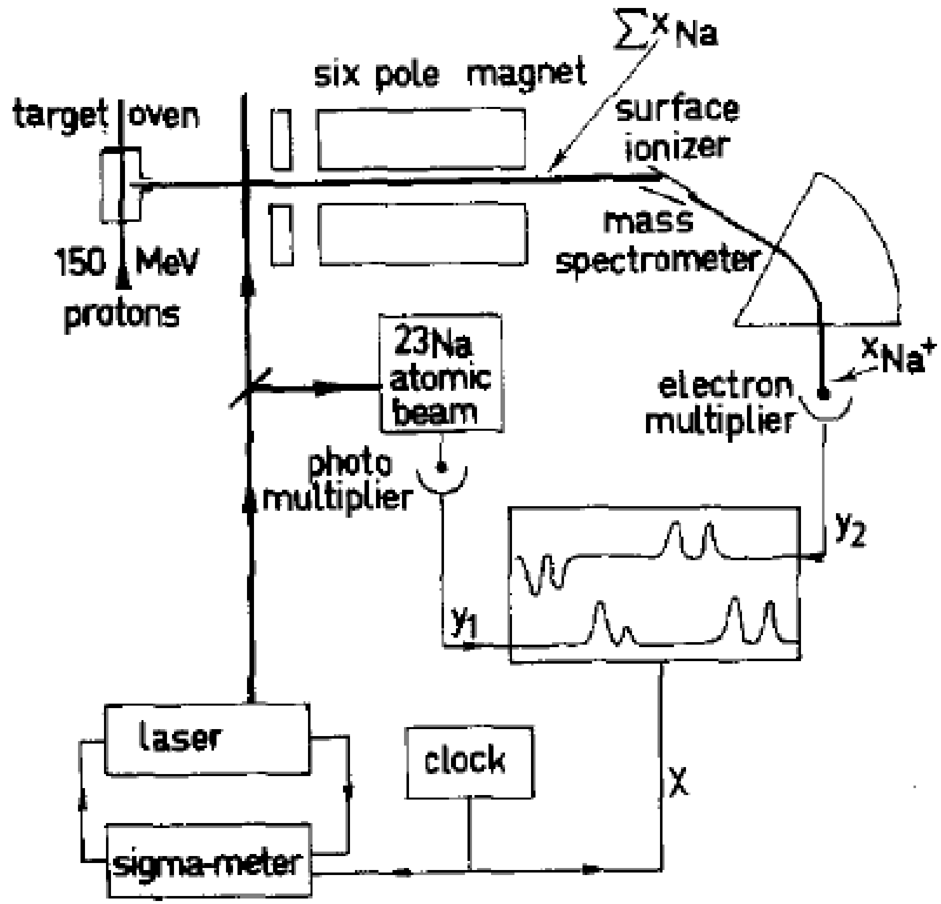
hyperfine spectroscopy HFS of Na isotopes
measuring nuclear magnetic and quadrupole moments

isotope production:

spallation reaction with ^{27}Al + 150 MeV p from an accelerator

$^{27}Al\,(p,3pxn)^{25-x}Na$

^{23}Na from atomic beam as reference



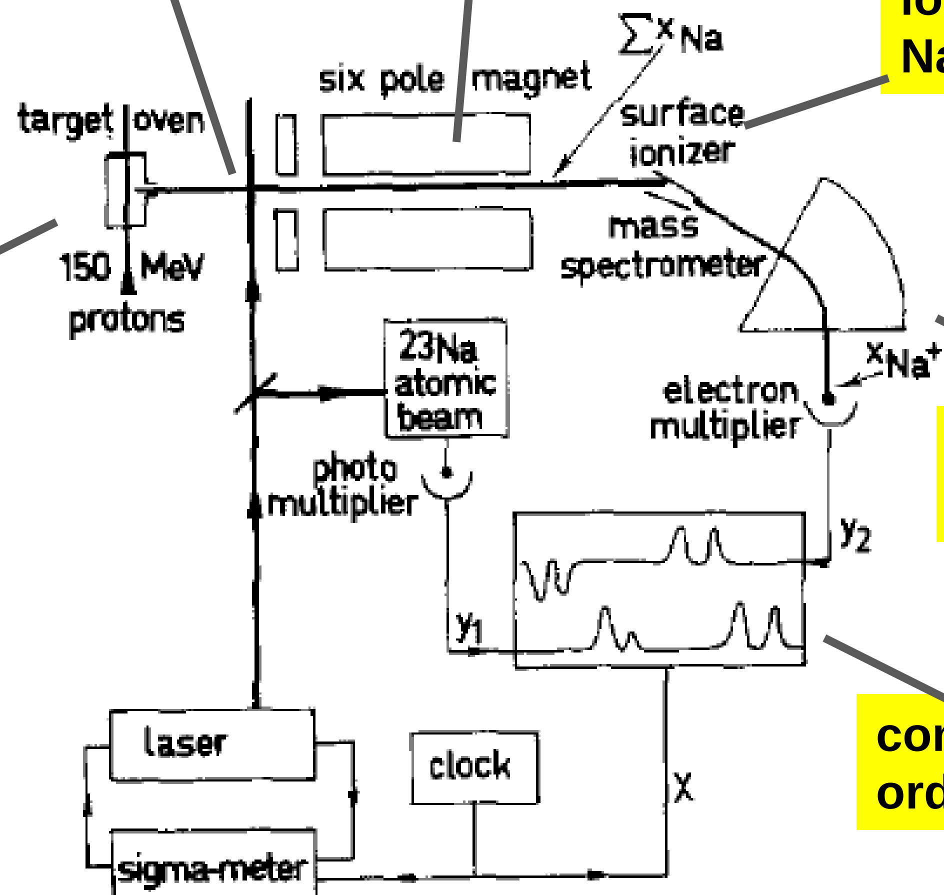
example of atom beam application for fundamental questions

laser excitation of all Na

selecting a hyperfine m_J state by focusing the neutral beam

ionize the focused Na atoms

creating Na isotopes



select and detect the isotope

compare with the ordinary Na spectrum

bis hierher 27.19.