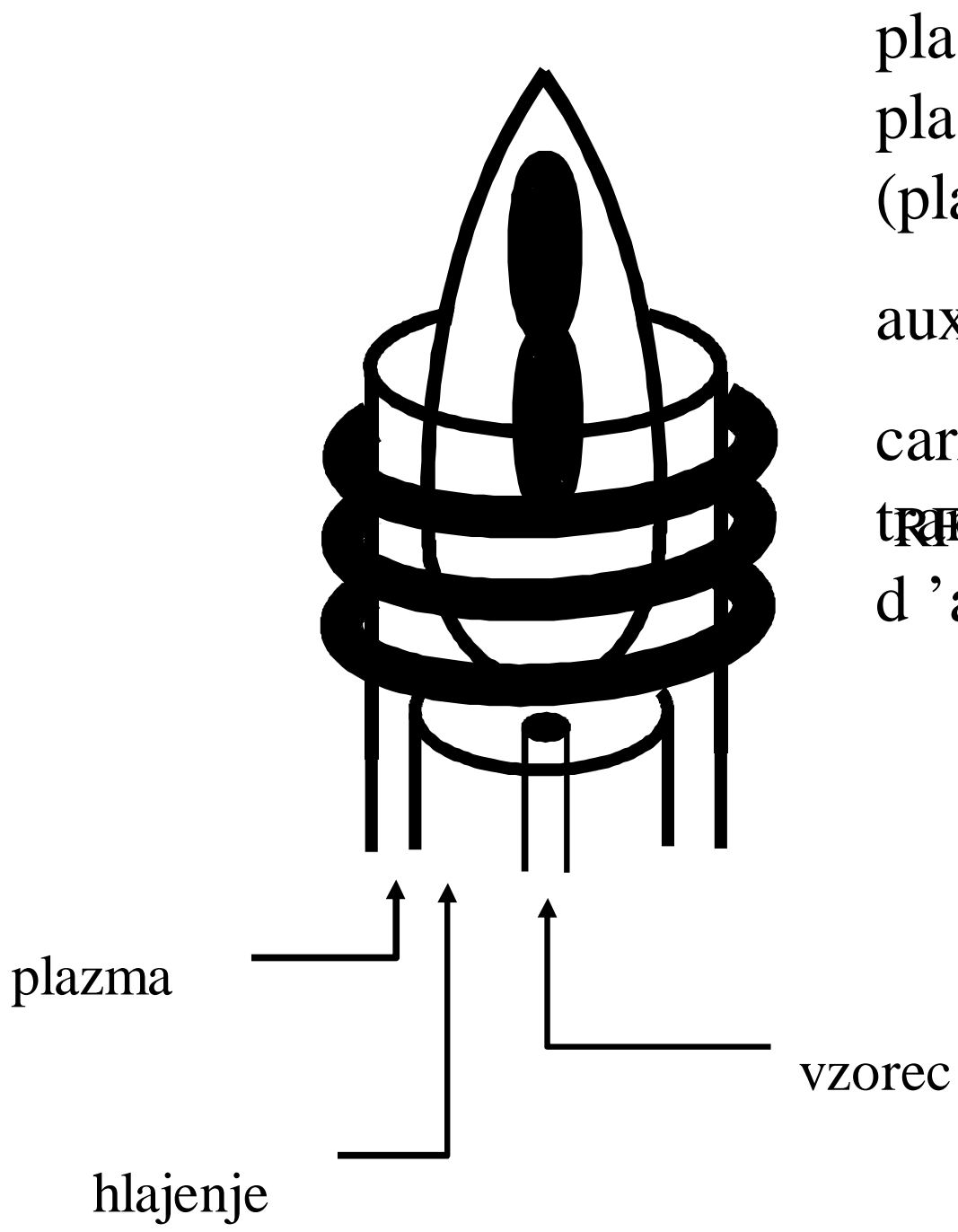


# Induktivno sklopljena plazma (ICP)

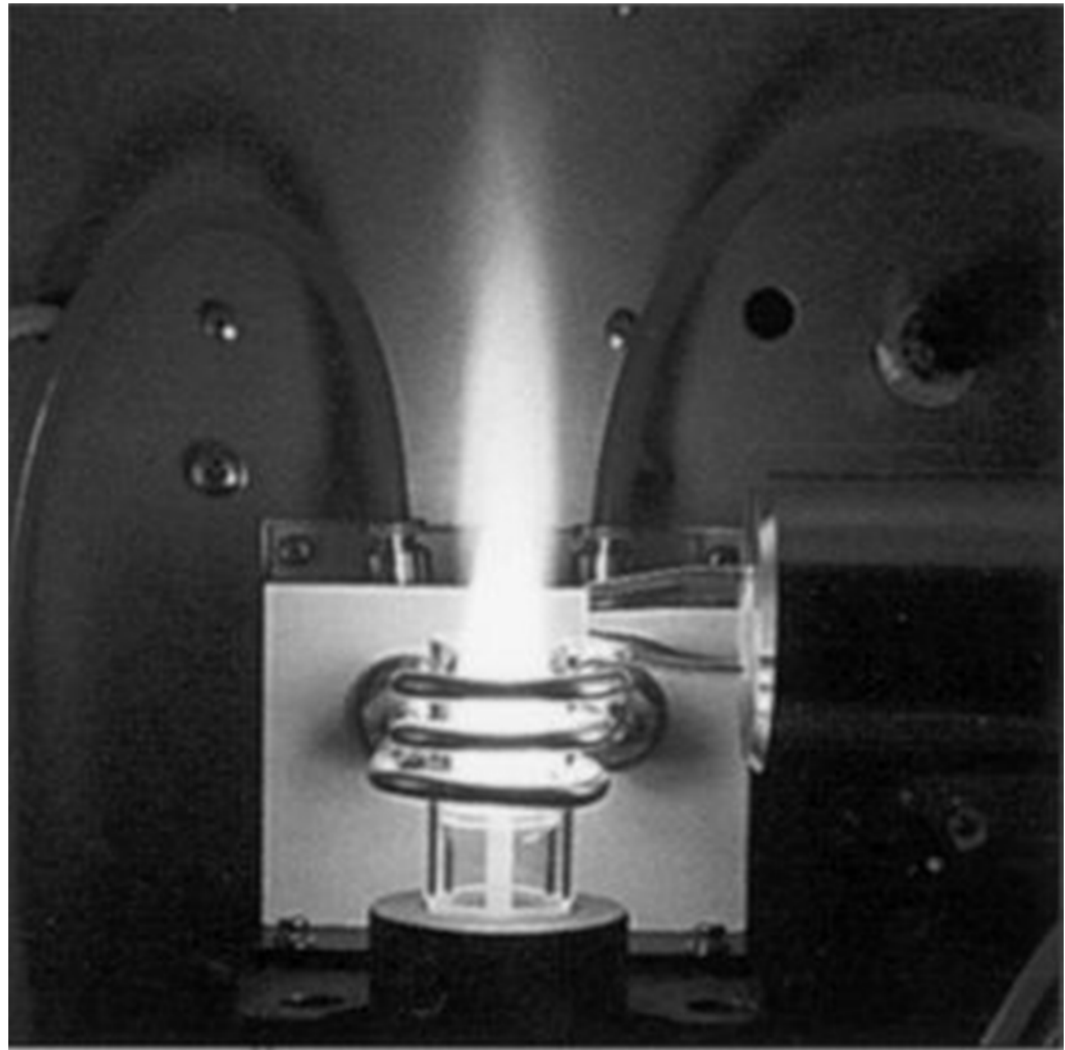
- **plazma** – električno prevodna plinska mešanica (kationi in elektroni)
- **Mnogo višja temperatura kot pri plamenu**
  - Možnost večelementne analize
  - > 40-50 elementov v 5 minutah
- **Prednosti**
  - enak odziv
  - hitra multielementna analiza
  - natančna in točna (0.3 – 3%)
  - malo interferenc
  - vzorec je lahko v plinski, tekoči ali trdni fazi
- **Slabosti**
  - Težave ob uporabi organskih topil



plasma =  
plasmagène  
(plasma)

auxiliary = auxiliaire

carrier =  
transporteur  
d'aérosol (aérosol)



# Plini za generiranje plazme

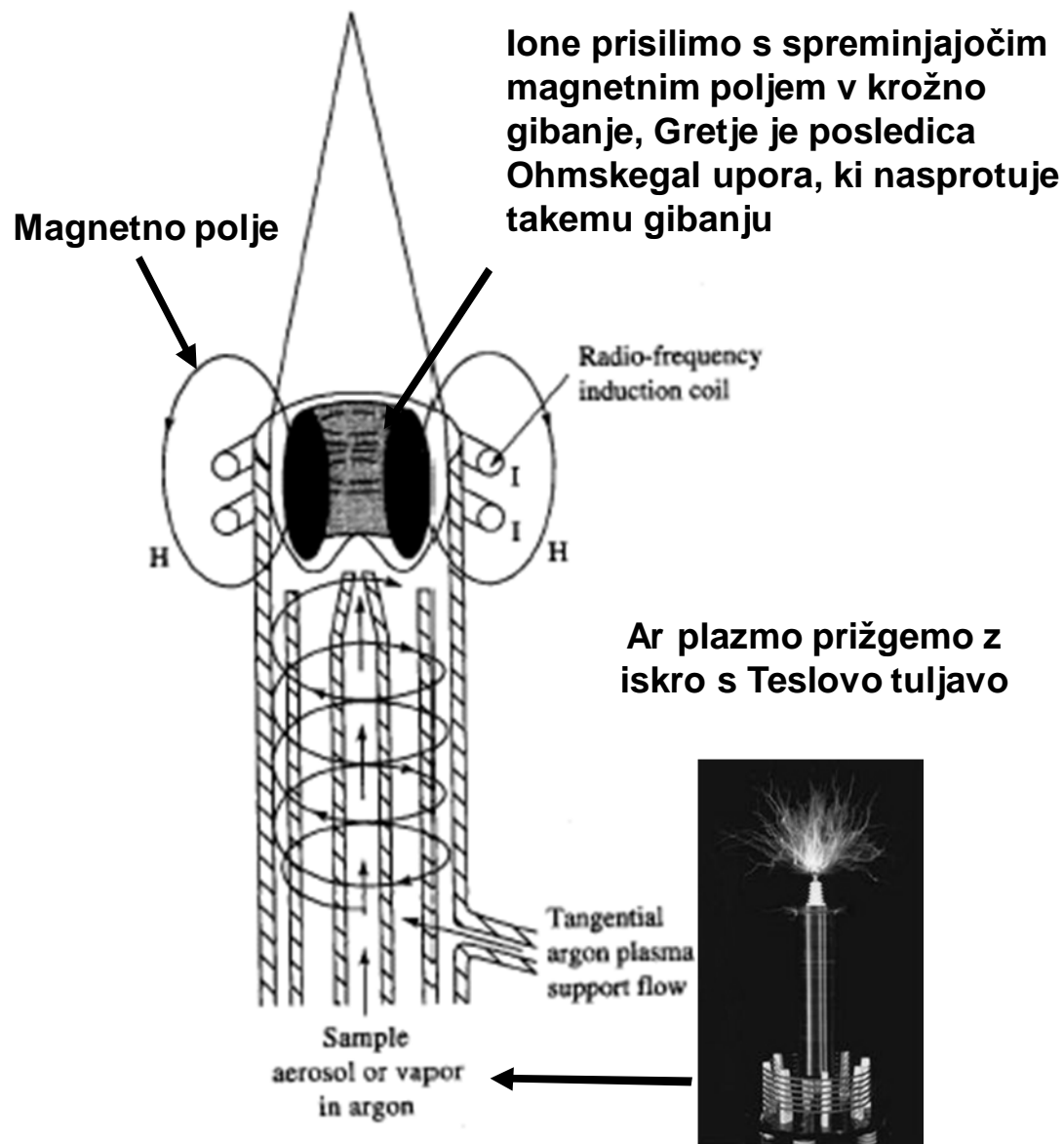
– žlahtni plini (He, Ar,...)

## ZAHTEVANE LASTNOSTI:

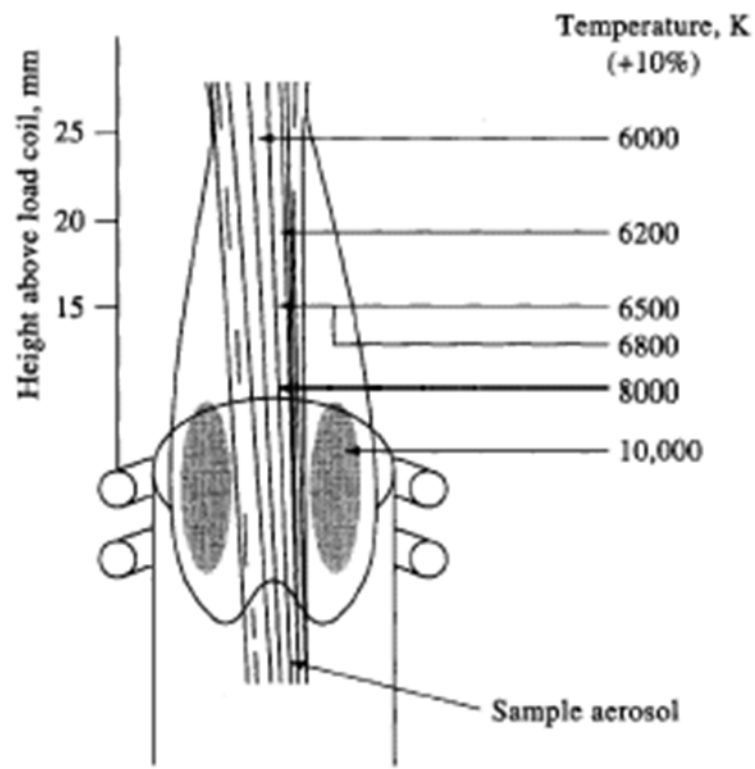
- ne tvorijo spojin
- visoka energija ionizacije (He = 24.6 eV; Ne = 21.56 eV, Ar = 15.76 eV)

## ICP emisijska spektroskopija

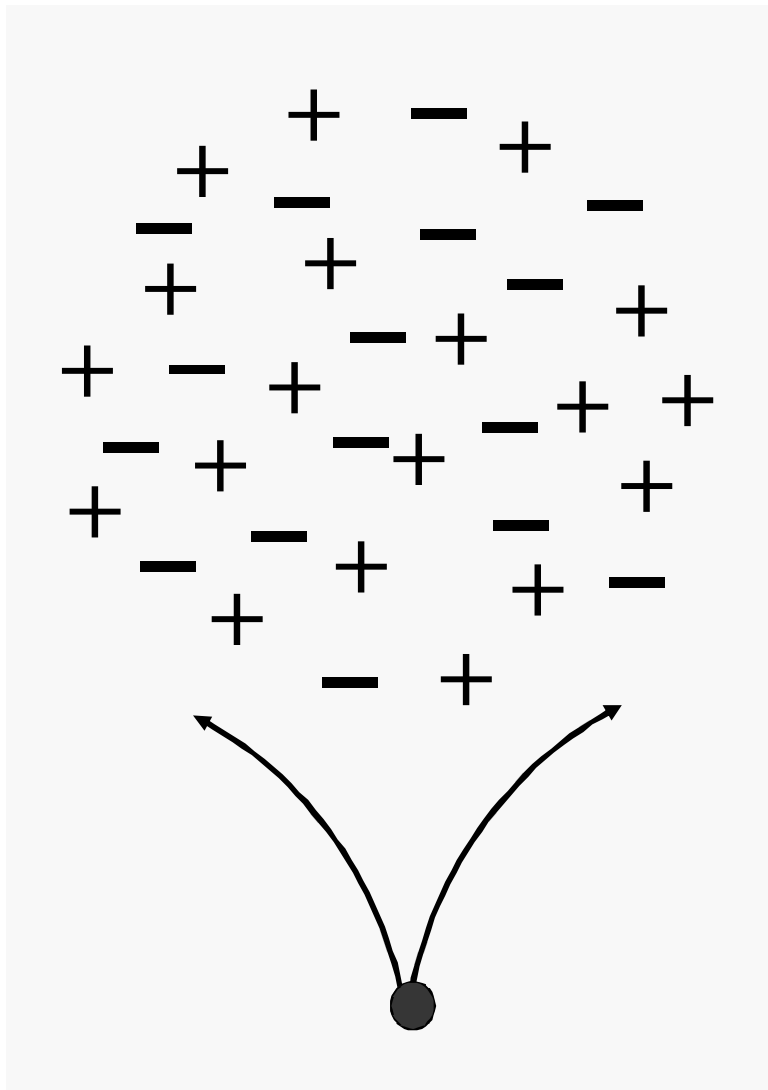
- uporablja visokotemperaturno plazmo za atomizacijo/vzbujanje vzorca
- večji del atomov se nahaja v vzbujenem stanju, poveča se emisijski signal, omogočeno je določevanje večjega števila elementov



## **Temperaturne regije v plazemski baklji**

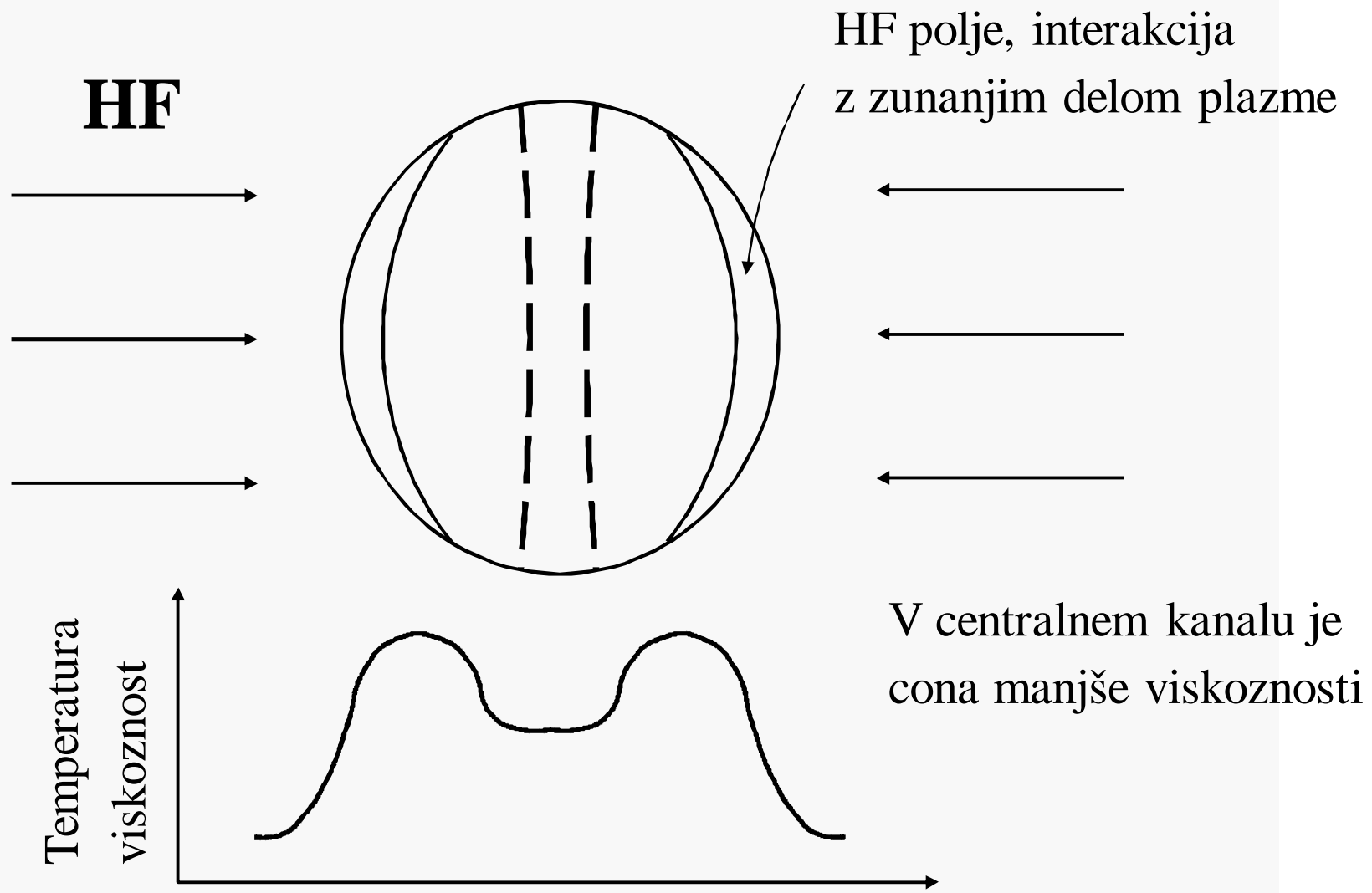


# Problemi pri vnosu vzorca



Zaradi električnega polja plazma "zavrača" vse tuje delce.

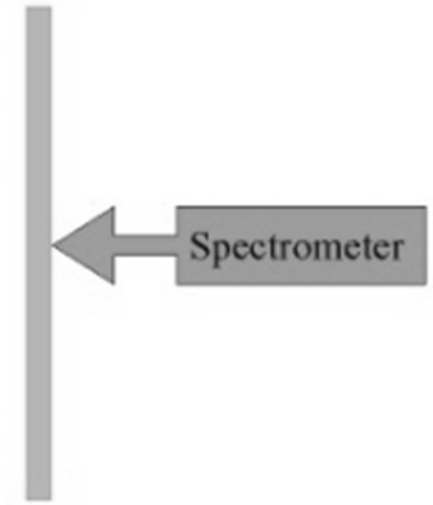
# Posledica visokofrekvenčnega polja



# Opazovalne pozicije

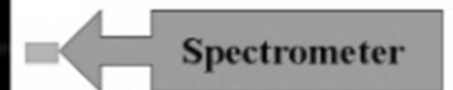
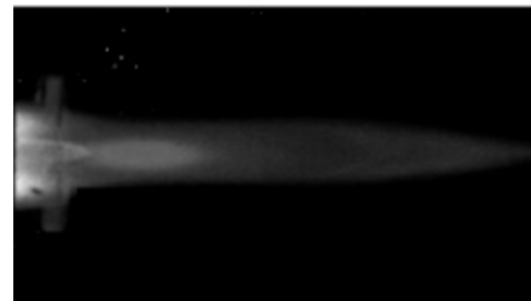
- Prednosti radialnega opazovanja
  - Should collect signal from the entire normal analytical zone (NAZ)
    - ni potrebna nastavitve bakle za posamezen element
    - manj interferenc
    - boljše meje detekcije za komplicirane matrikse
    - uporablja se lahko vsak matrix
  - manjša poraba argona

A Radial Slit



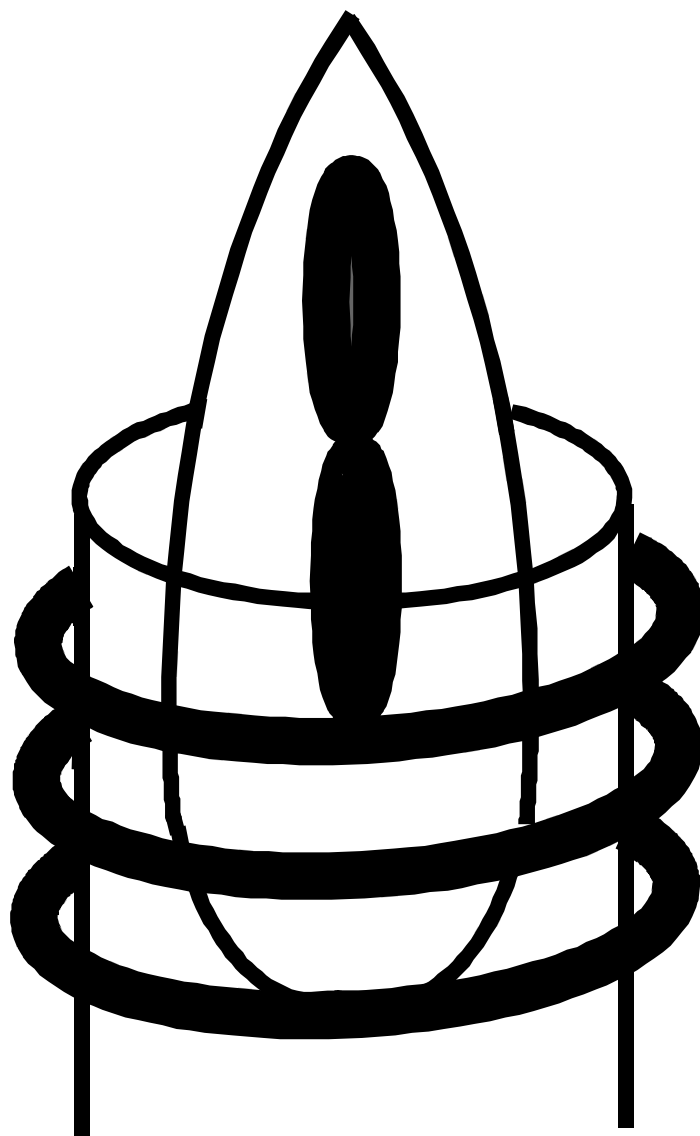
- Prednosti aksialnega pogleda
  - Boljša meja detekcije za enostavne matrikse

An Axial Slit





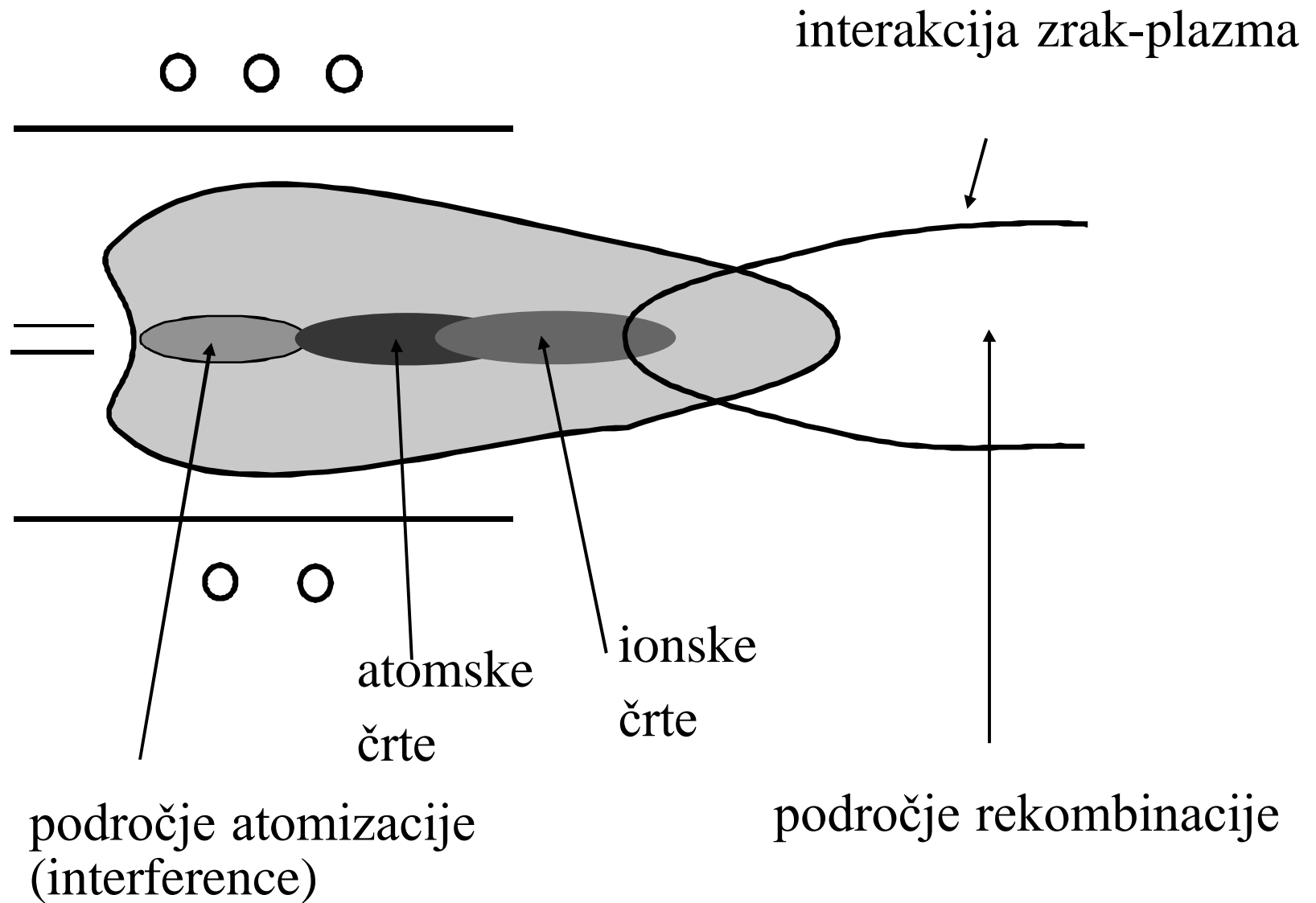
## *VERTIKALNO OPAZOVANJE*



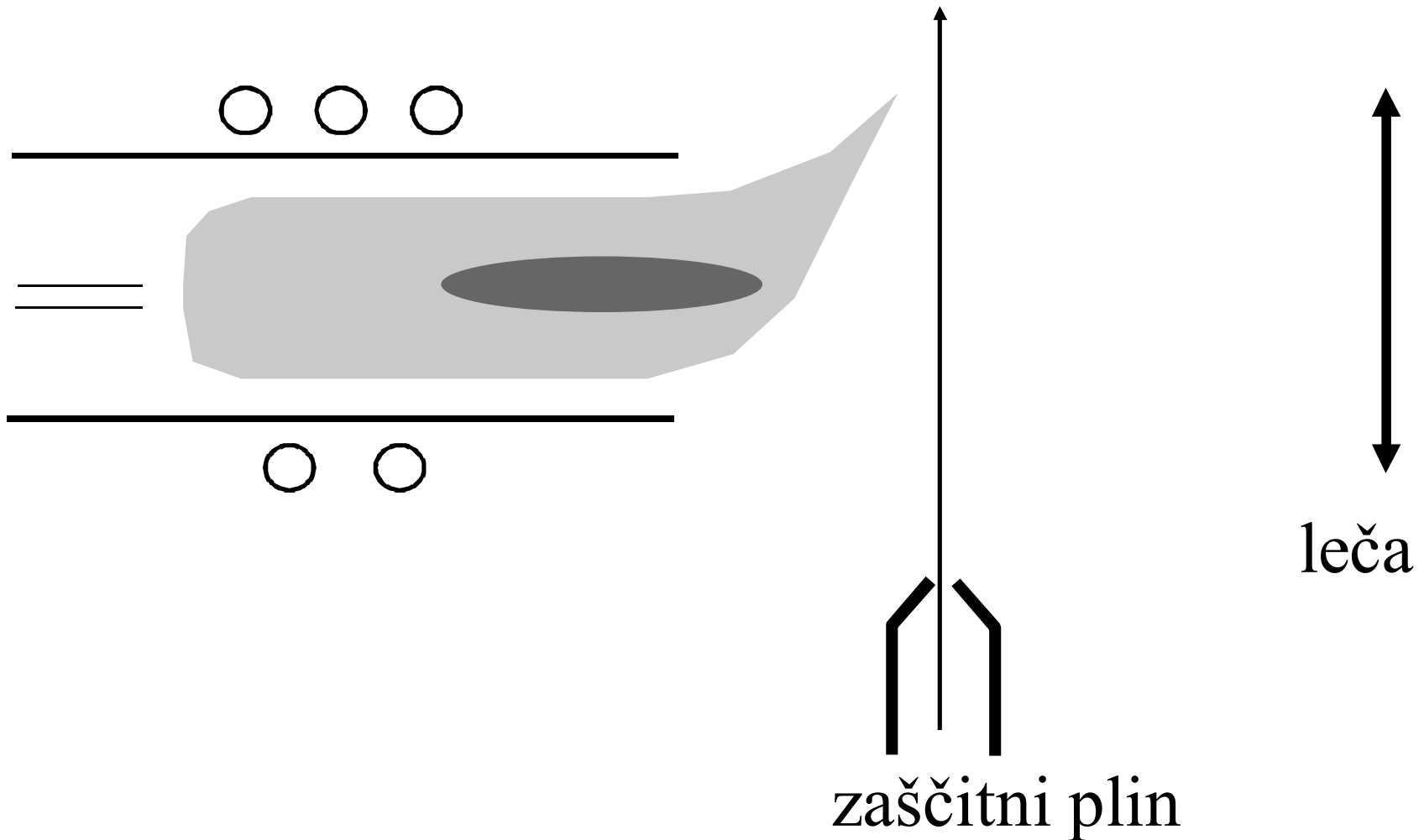
← ionske črte

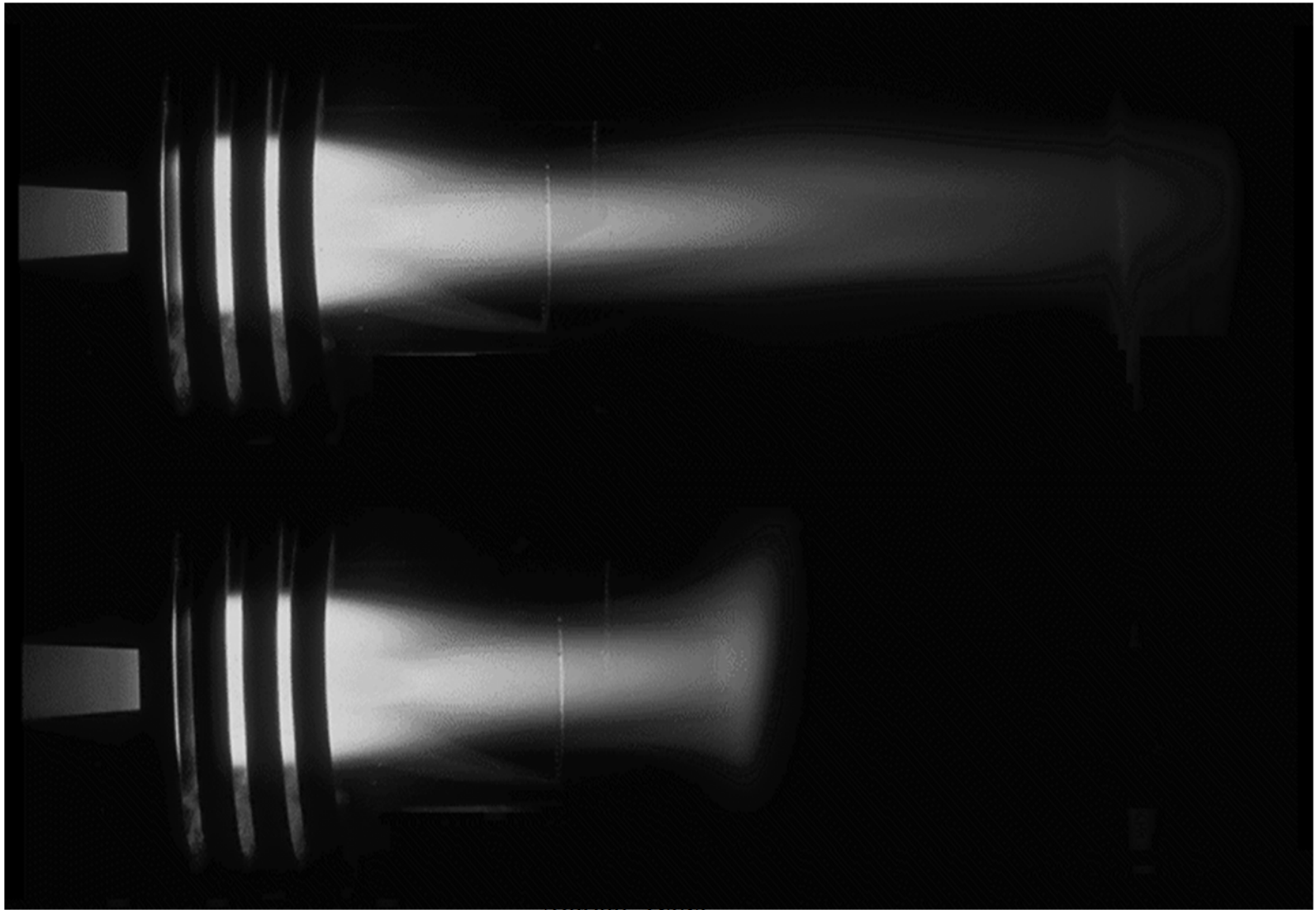
← atomske črte

# *Cone v plazmi:*



# *Aksialno opazovanje: zaščitni plin (shear gas)*





1964-1965

# Typical detection limits

< 1 ppb

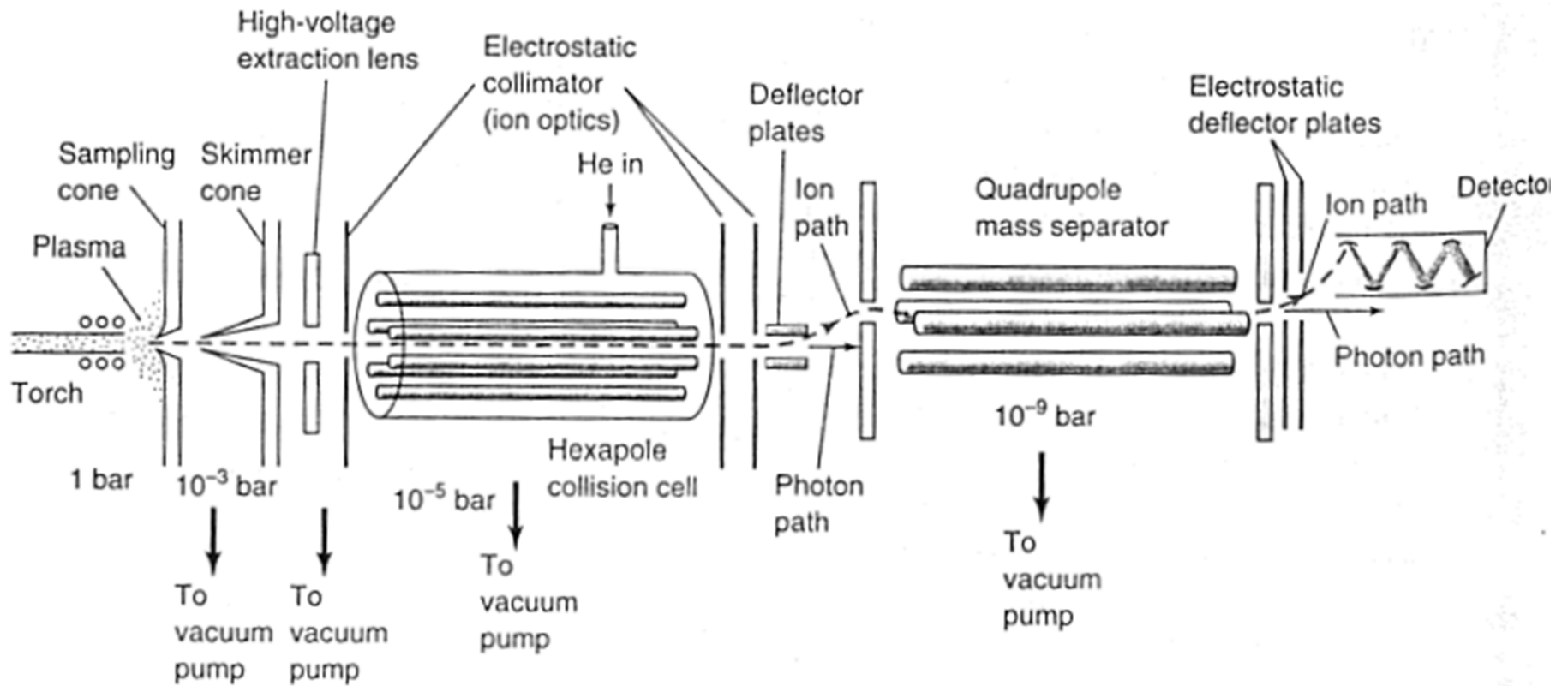
< 10 ppb

< 5 ppb

> 10 ppb

IA 1 <b>H</b> 1.00794	IIA 4 <b>Be</b> 9.01218											III A 5 <b>B</b> 10.811	IVA 6 <b>C</b> 12.011	V A 7 <b>N</b> 14.0064	VI A 8 <b>O</b> 15.9994	VII A 9 <b>F</b> 18.9984	VIII A 10 <b>Ne</b> 20.180	
11 <b>Li</b> 6.941	12 <b>Na</b> 22.98976928	13 <b>Mg</b> 24.304	21 <b>Sc</b> 44.955912	22 <b>Ti</b> 47.88	23 <b>V</b> 50.9415	24 <b>Cr</b> 51.9961	25 <b>Mn</b> 54.938045	26 <b>Fe</b> 55.845	27 <b>Co</b> 58.933195	28 <b>Ni</b> 58.71	29 <b>Cu</b> 63.546	30 <b>Zn</b> 65.38	31 <b>Ga</b> 69.723	32 <b>Ge</b> 72.64	33 <b>As</b> 74.9216	34 <b>Se</b> 78.96	35 <b>Br</b> 79.904	36 <b>Kr</b> 83.80
19 <b>K</b> 39.0983	20 <b>Ca</b> 40.078	39 <b>Y</b> 88.905848	40 <b>Zr</b> 91.224	41 <b>Nb</b> 92.90638	42 <b>Mo</b> 95.94	43 <b>Tc</b> 98	44 <b>Ru</b> 101.07	45 <b>Rh</b> 102.9055	46 <b>Pd</b> 106.42	47 <b>Ag</b> 107.8682	48 <b>Cd</b> 112.411	49 <b>In</b> 114.818	50 <b>Sn</b> 118.710	51 <b>Sb</b> 121.757	52 <b>Te</b> 127.603	53 <b>I</b> 126.90547	54 <b>Xe</b> 131.29	
37 <b>Rb</b> 85.4678	38 <b>Sr</b> 87.62	55 <b>Ba</b> 137.327	56 <b>Hf</b> 178.49	57 <b>Ta</b> 180.94788	58 <b>W</b> 183.84	59 <b>Re</b> 186.207	60 <b>Os</b> 190.23	61 <b>Ir</b> 192.222	62 <b>Pt</b> 195.084	63 <b>Au</b> 196.966569	64 <b>Hg</b> 200.59	65 <b>Tl</b> 204.3833	66 <b>Pb</b> 207.2	67 <b>Bi</b> 208.9804	68 <b>Po</b> 209	69 <b>At</b> 210	70 <b>Rn</b> 222	
55 <b>Fr</b> 223	56 <b>Ra</b> 226	57 <b>Ac</b> 227																
			58 <b>Ce</b> 140.12	59 <b>Pr</b> 140.90765	60 <b>Nd</b> 144.242	61 <b>Pm</b> 145	62 <b>Sm</b> 150.36	63 <b>Eu</b> 151.964	64 <b>Gd</b> 157.25	65 <b>Tb</b> 158.92534	66 <b>Dy</b> 162.50014	67 <b>Ho</b> 164.930329	68 <b>Er</b> 167.2593	69 <b>Tm</b> 168.93032	70 <b>Yb</b> 173.054688	71 <b>Lu</b> 174.96706		
			88 <b>Th</b> 232.0377	89 <b>Pa</b> 231	90 <b>U</b> 238.02891													

# ICP-MS



# Primerjava metod

	Flame absorption	Furnace absorption	Plasma emission	Plasma-mass spectrometry
Detection limits (ng/g)	10-1 000	0.01-1	0.1-10	0.000 01-0.000 1
Linear range	10 <sup>2</sup>	10 <sup>2</sup>	10 <sup>5</sup>	10 <sup>8</sup>
Precision				
short term (5-10 min)	0.1-1%	0.5-5%	0.1-2%	0.5-2%
long term (hours)	1-10%	1-10%	1-5%	<5%
Interferences				
spectral	very few	very few	many	few
chemical	many	very many	very few	some
mass	—	—	—	many
Sample throughput	10-15 s/element	3-4 min/element	6-60 elements/min	all elements in 2-5 min
Dissolved solid	0.5-5%	>20% slurries & solids	1-20%	0.1-0.4%
Sample volume	large	very small	medium	medium
Purchase cost	1	2	4-9	10-15

SOURCE: Adapted from TJA Solutions, Franklin, MA.