Max-Planck-Institut
für Plasmaphysik

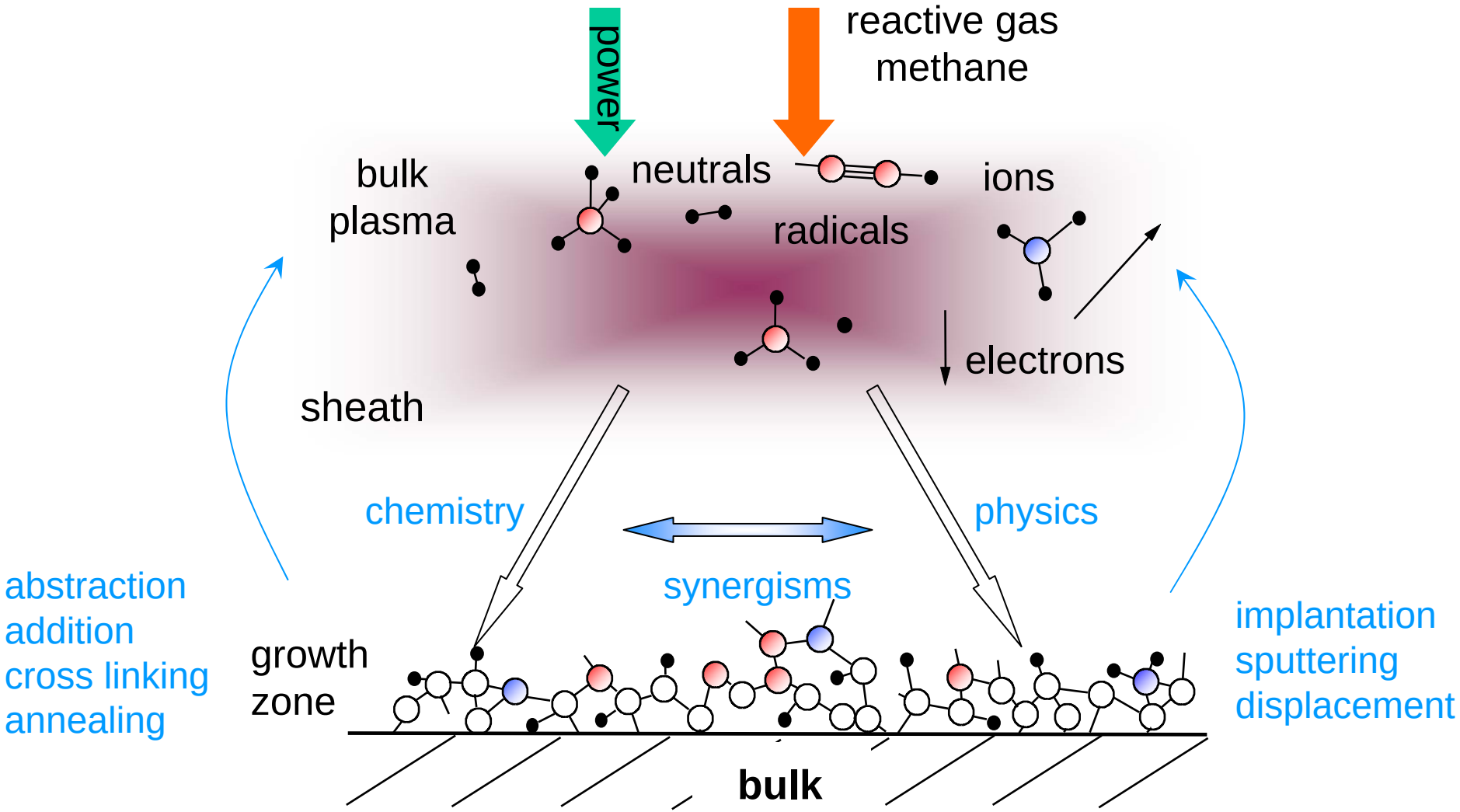
Zeitaufgelöste Messungen von transienten und stabilen Spezies in gepulsten induktiv gekoppelten Argon/Methan Entladungen

Vasile Vartolomei, Thomas Schwarz-Selinger, Wolfgang Jacob

Arbeitsgruppe Reaktive Plasmaprozesse, Bereich Materialforschung

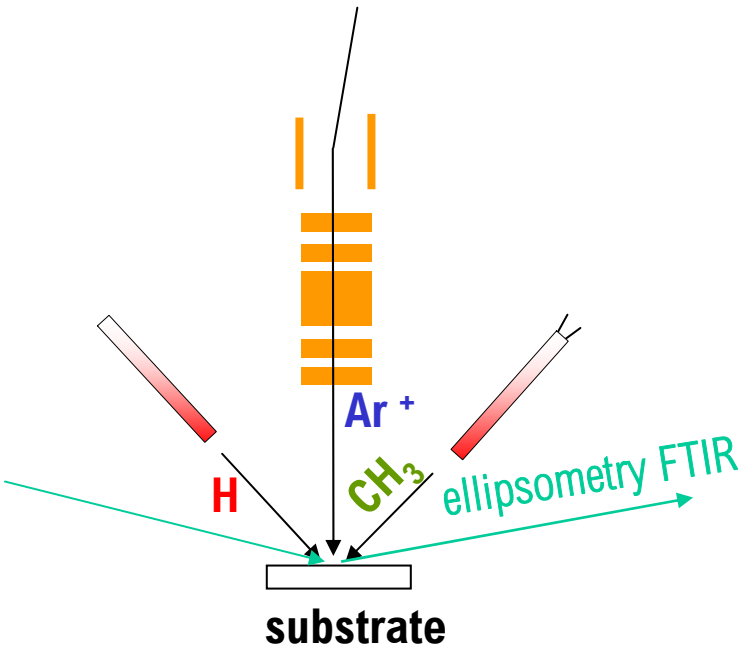
XII. Erfahrungsaustausch
Oberflächentechnologie mit Plasma- und Ionenstrahlprozessen
Mühlleithen 14. März 2006

how do a-C:H films grow?



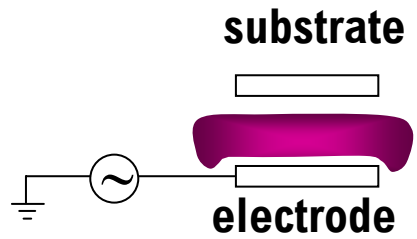
film growth and erosion studies: two approaches

1. quantified beam experiments



+ "easy" interpretation
+ isolation of microscopic mechanism
– "artificial plasma"

2. plasma experiments

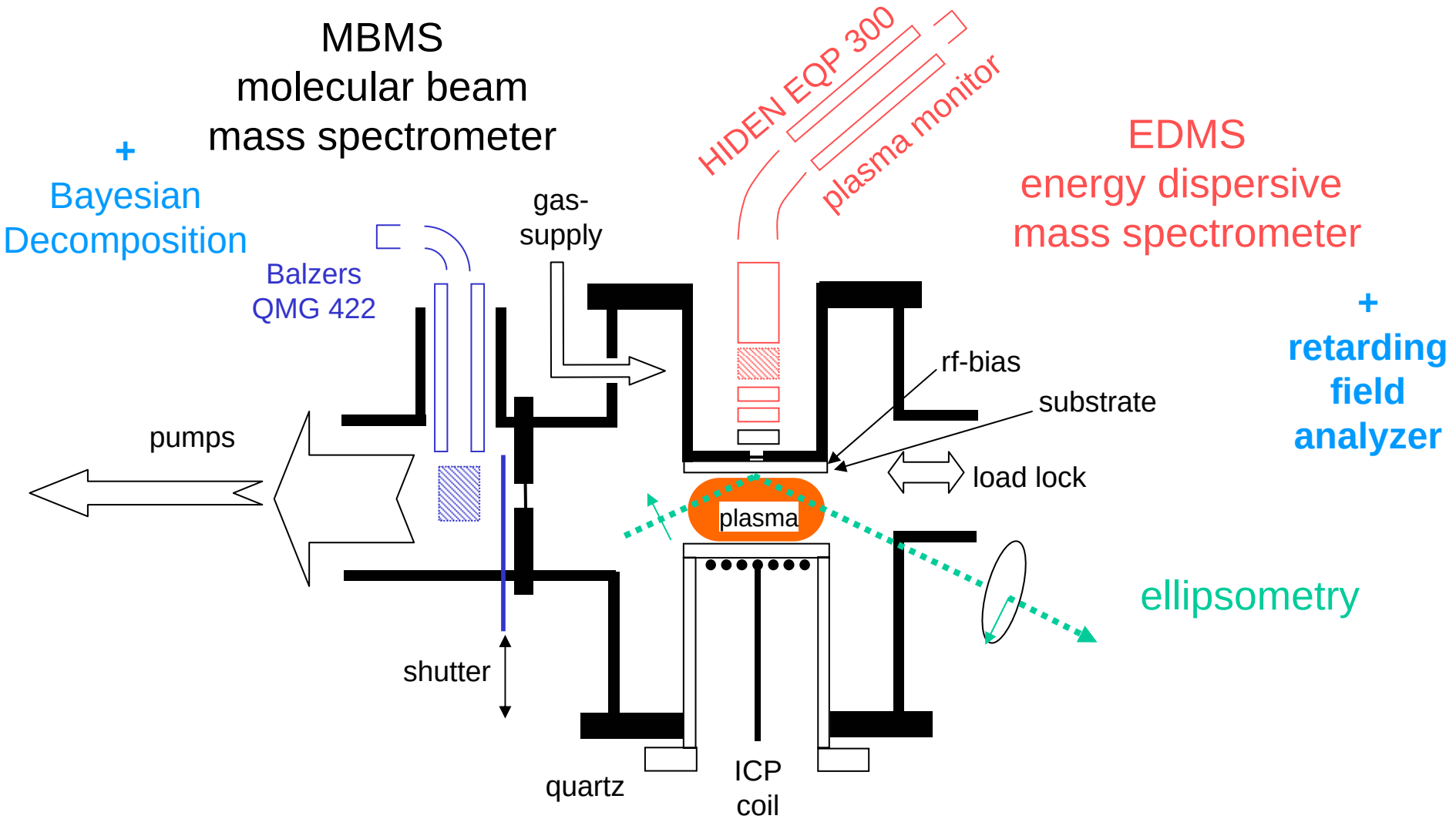


ECR
cc-rf plasma
pulsed ICP

diagnostics: ellipsometry
FTIR
QMS, PM, RFA
cavities…

+ real life
– interpretation ambiguous
complex particle zoo
quantification of fluxes?

experimental setup



modeling of the ICP gas phase

starting point:

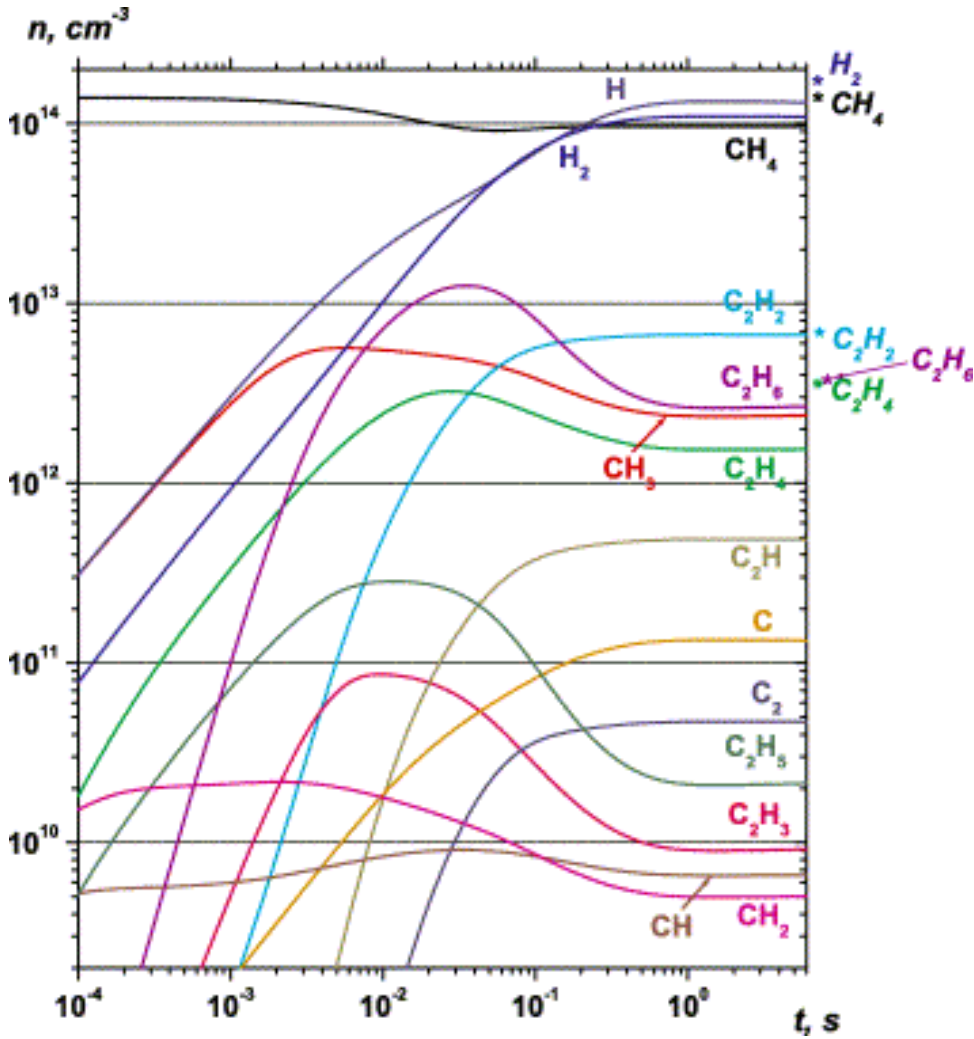
0 dimensional particle balance

$$\frac{\mathrm{d}n_\alpha}{\mathrm{d}t} = \sum_{\beta,\gamma} R^\alpha_{\beta\gamma} n_\beta n_\gamma - n_\alpha \sum_{\beta,\gamma} R^\beta_{\alpha,\gamma} n_\gamma + S_\alpha - P_\alpha$$

final goal:

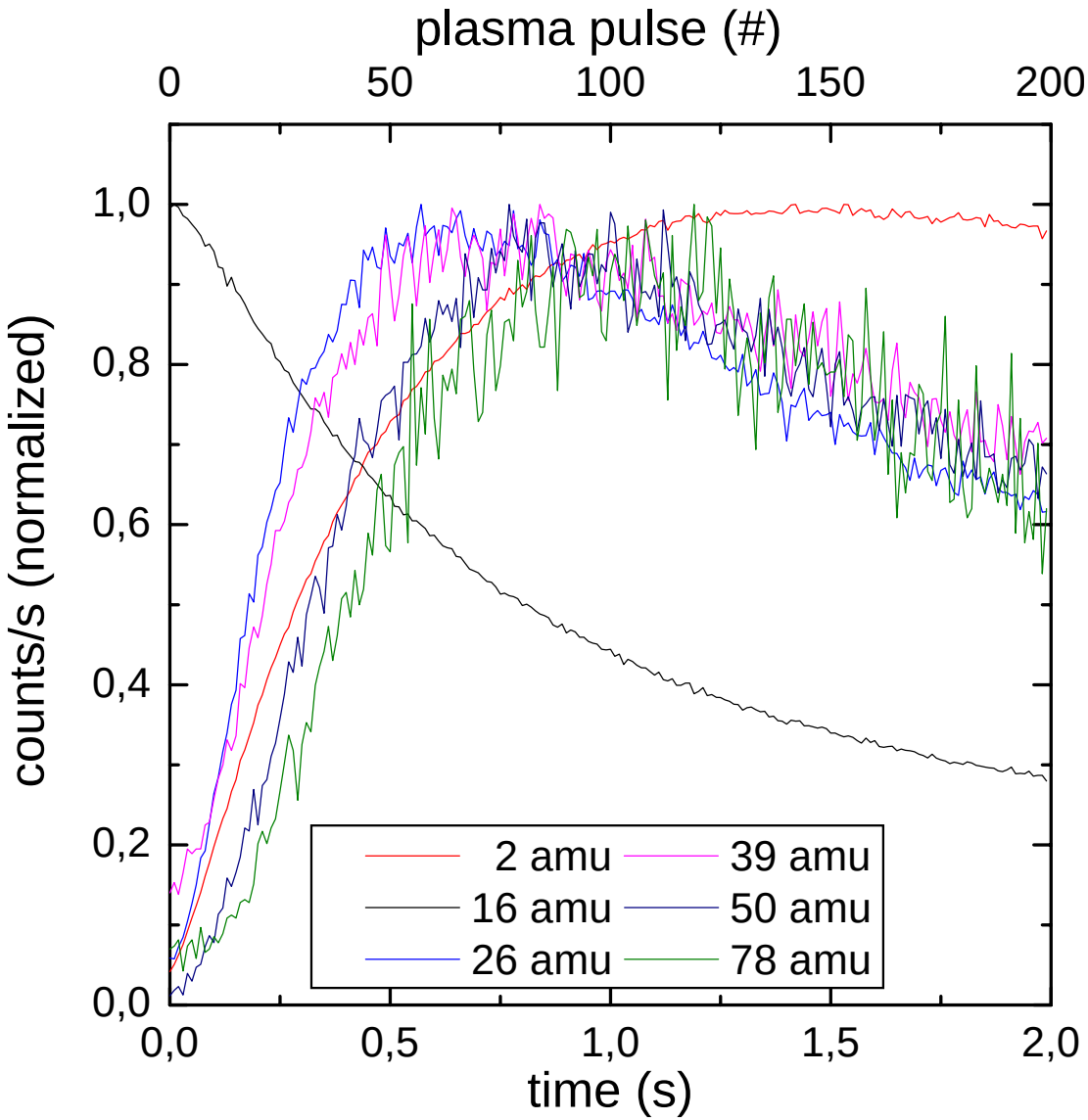
combined plasma surface model

(simpler hydrogen case first?)



K. Matyash et al., J. of Nuclear Materials 313-316 (2003) 434-

„burn in“ phase of pulsed plasma experiment

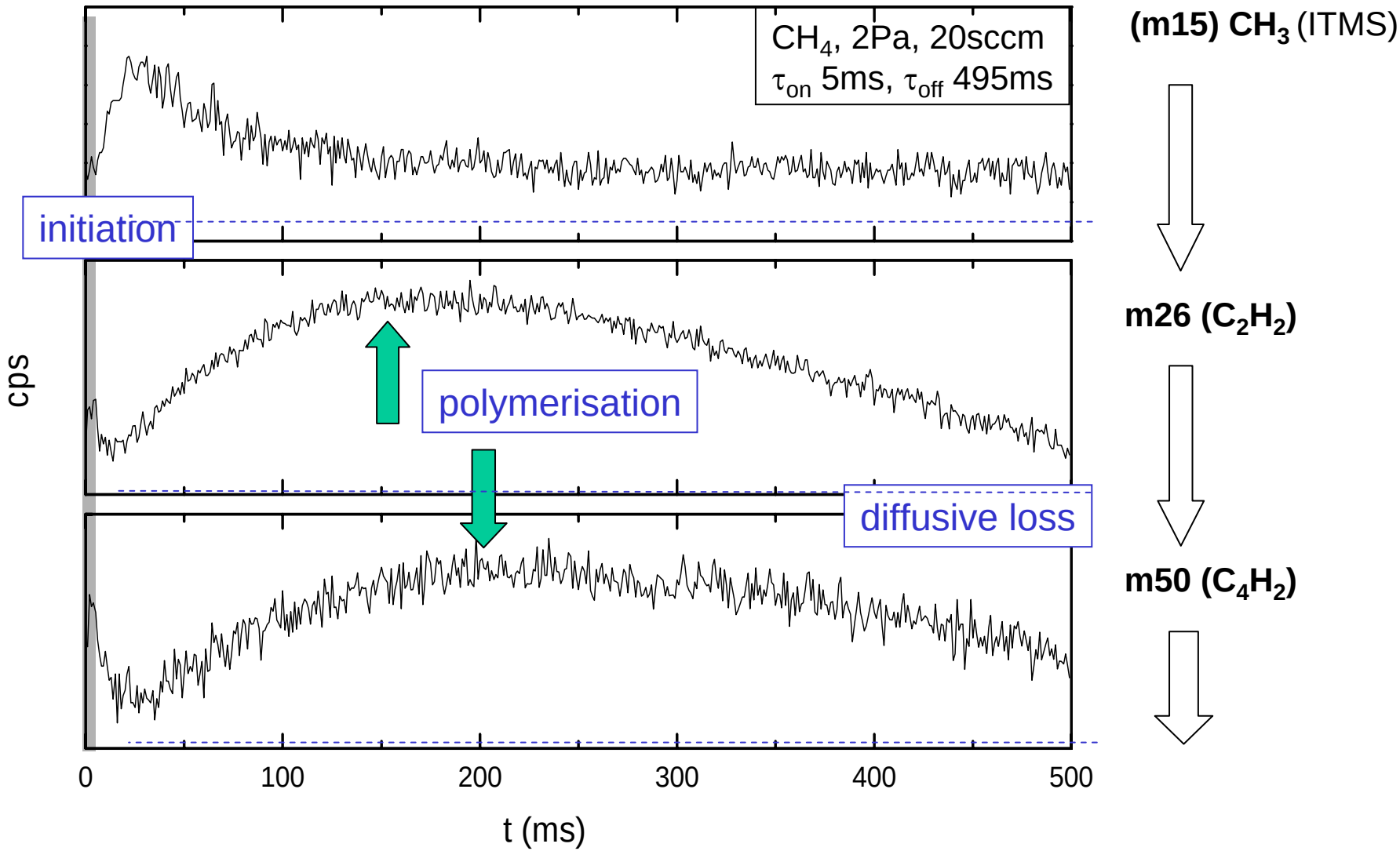


parameters:

feed gas	CH_4
flux	20 sccm
pressure	2 Pa
power	300 W
τ_{on}	3 ms
τ_{off}	7 ms
E_{mean}	70 eV

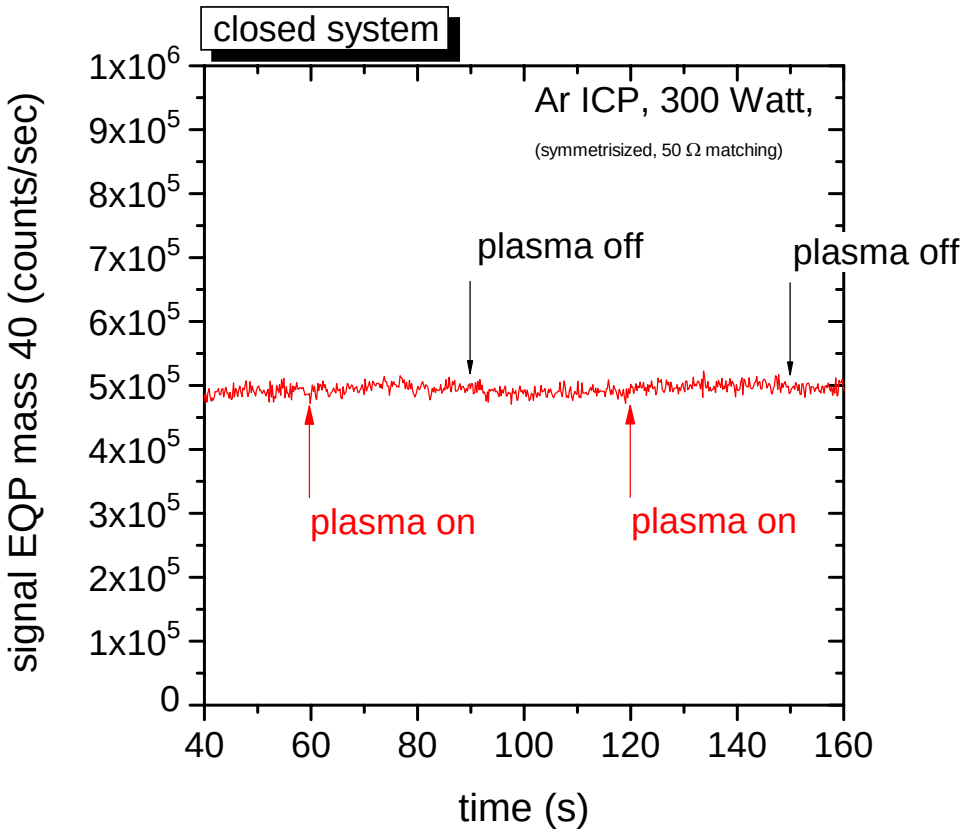
M. Bauer, 2004

time-resolved mass spectroscopy

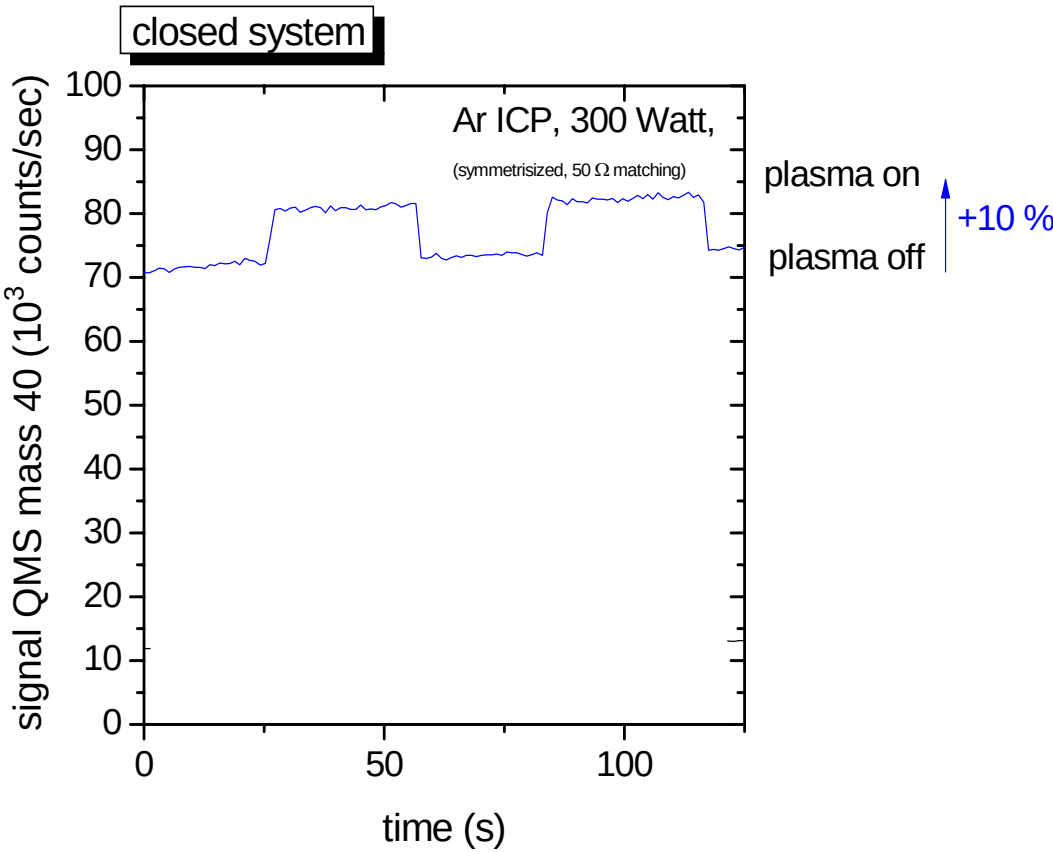


take a simplified case: Argon

substrate electrode

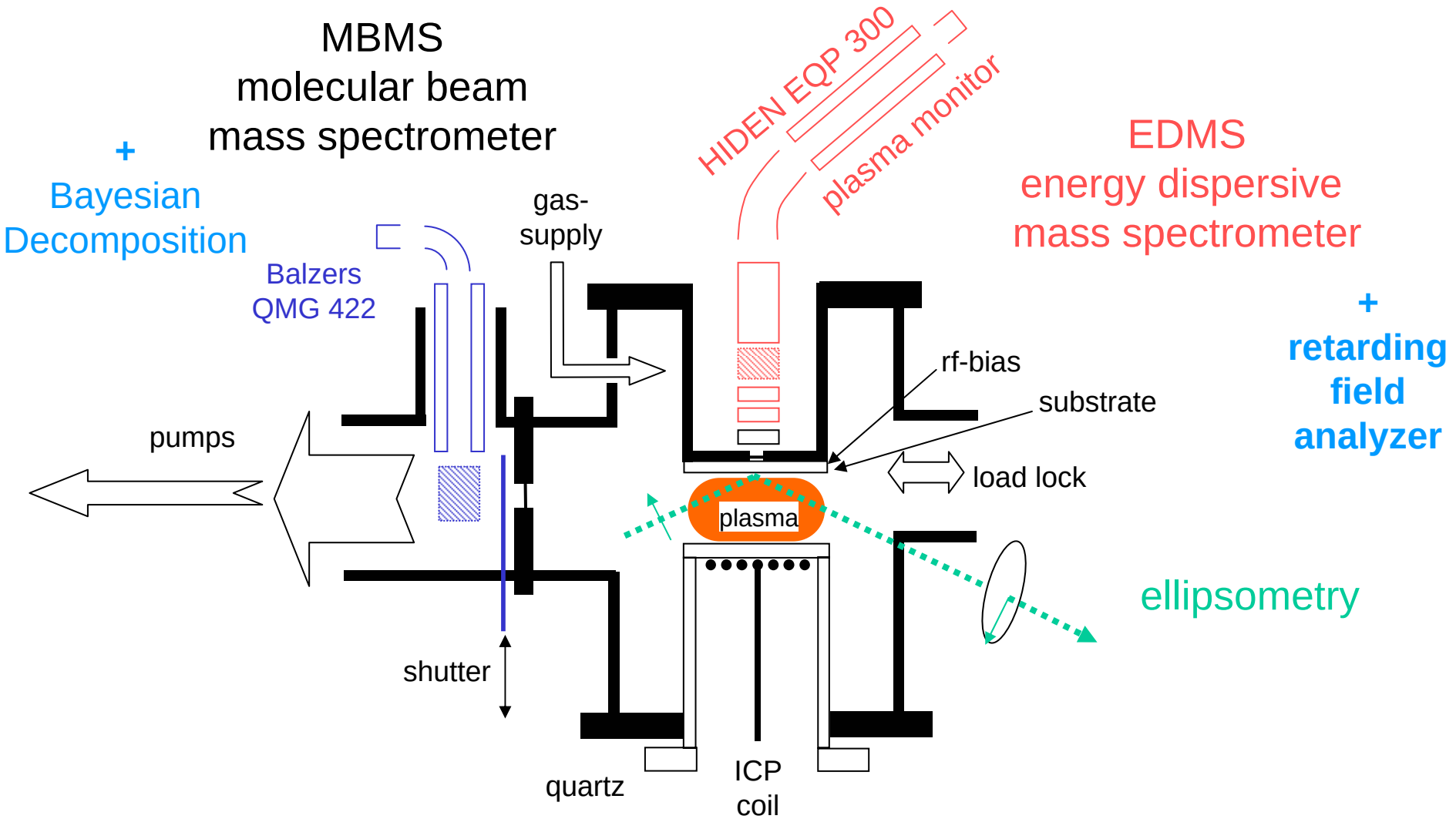


vessel wall



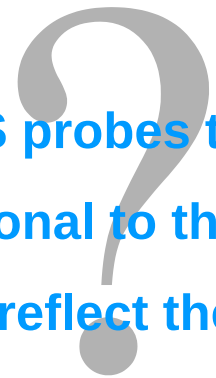
What do we really measure?

experimental setup



What do we measure with a mass spectrometer?

Quantitative Mass Spectrometry of Reactive Plasmas



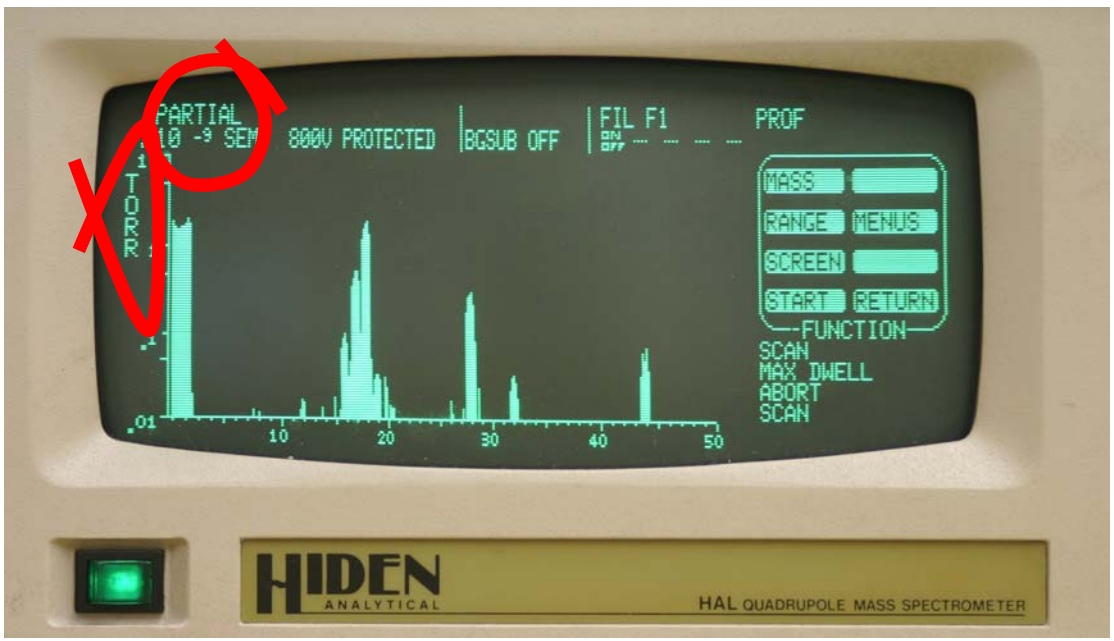
“a differentially pumped QMS probes the **density** in front of the orifice”*

“the signal is proportional to the **flux** through the orifice”*

“the intensities reflect the **partial pressures**”*

Quantitative Mass Spectrometry of Reactive Plasmas

Just read the instruments display!



Outline

Elements of a Quadrupole Mass Analyzer

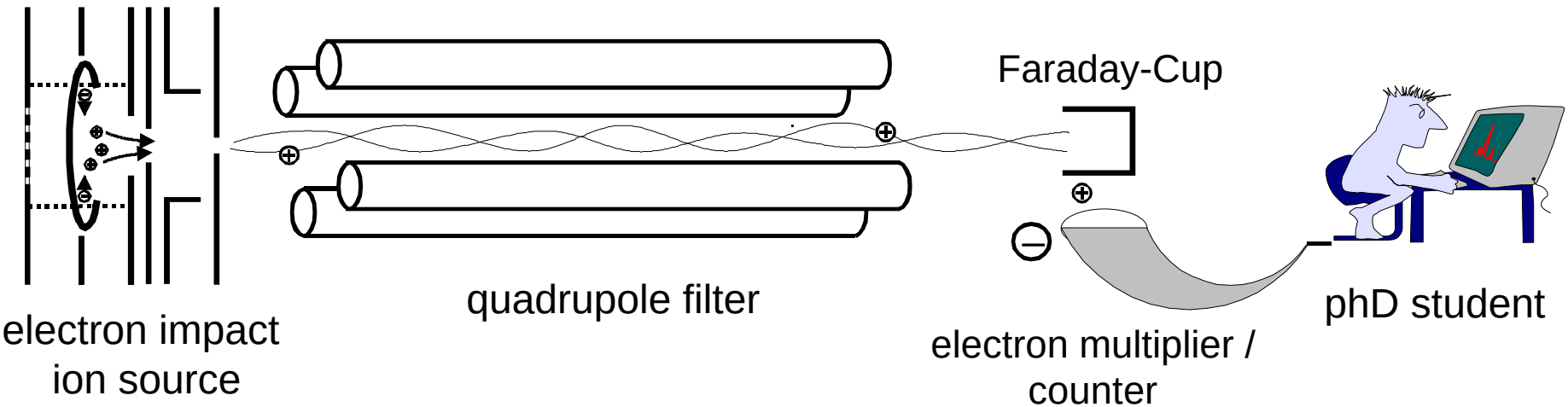
pressure reduction / extraction

ionization

mass separation

detection / amplification /

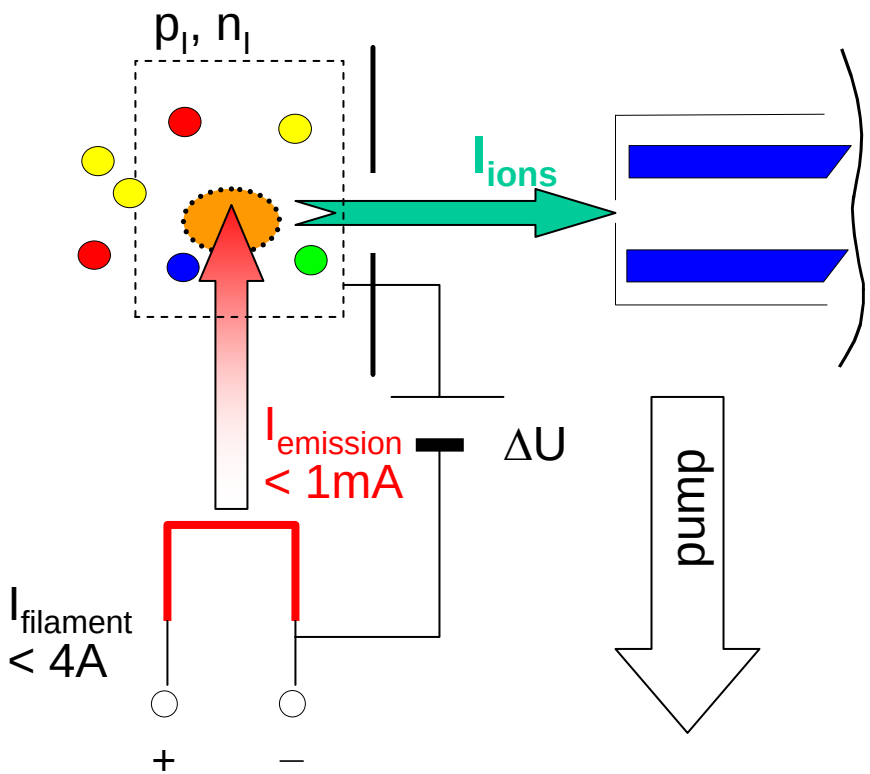
interpretation



orifice / capillary

What do we really measure?

electron impact ionization in the ionizer:



signal $\propto I_{ions}$

signal $\propto I_{emiss} \times N$

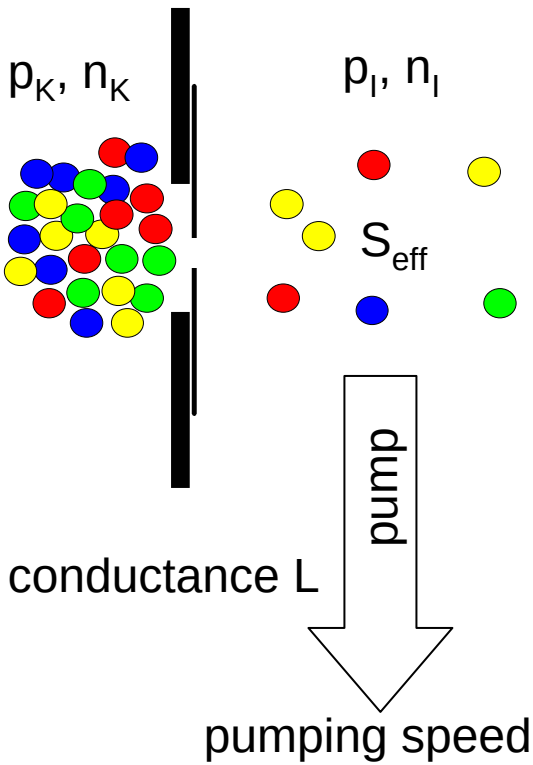
signal $\propto$ density in the effective volume

What do we really measure? flux? pressure? density?

density in the effective volume results because of the balance between:

influx: $\Gamma_{in} = n_K \cdot L_A = r^2\pi \cdot j_K = \frac{1}{4}\, r^2\pi \cdot n_K\, v_K$ (thin aperture)

outflux: $\Gamma_{out} = n_I \cdot S_{eff}$, $(S_{eff} >> L_A)$



balance: $\Gamma_{in} = \Gamma_{out}$

$$n_I = \frac{1}{4}\,\frac{r^2\pi}{S_{eff}}\, n_K\, v_K$$

but: $$\frac{1}{S_{eff}} = \frac{S+L}{S\cdot L} = \frac{1}{L}\left(1+\frac{L}{S}\right) \approx \frac{1}{L} \quad , \quad (L<<S)$$

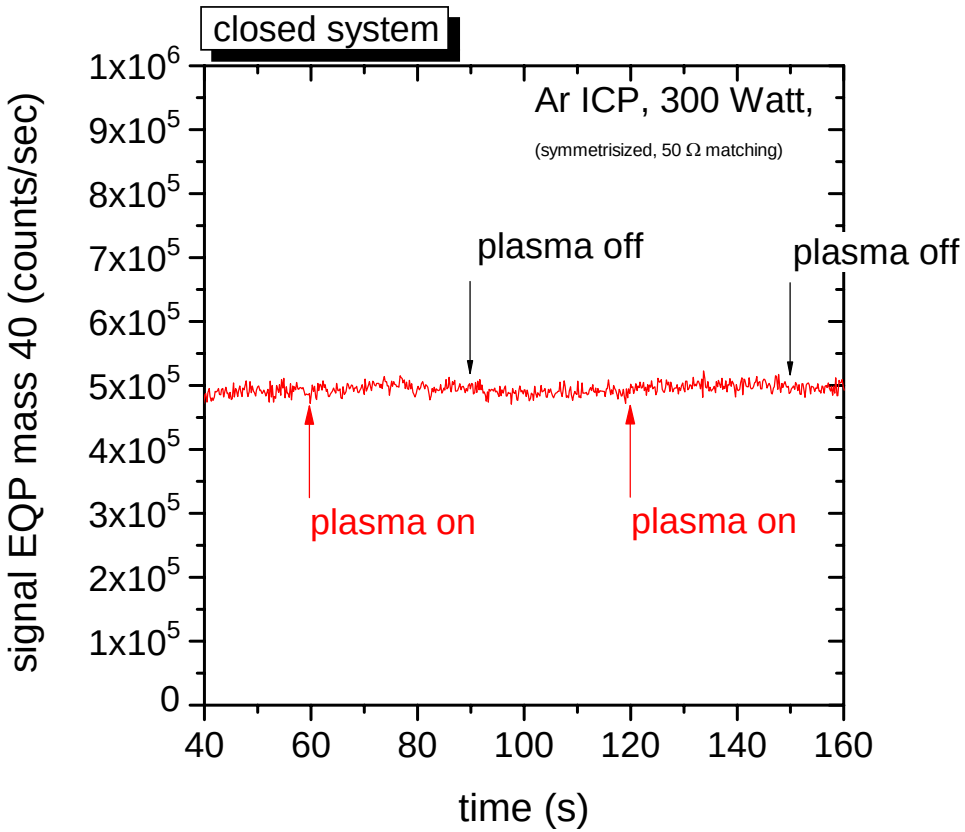
$L \propto v$ (molecular flow)

n_I = const. · n_K (if $v = v_K$)

$$n_i \propto \sqrt{\frac{T_0}{T_i}} \cdot n_0$$

Take a simplified case: Argon

substrate electrode



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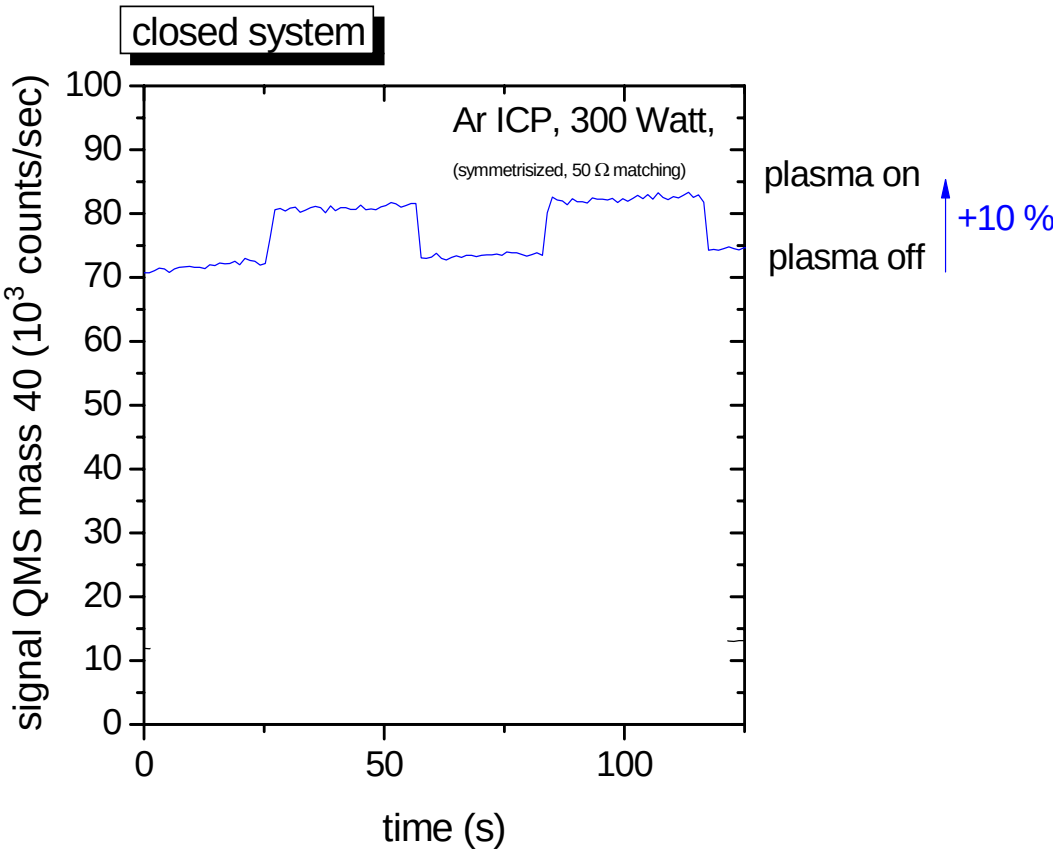

What do we really measure?

conclusion

- **Identification and Quantification of measured data:**

  ions, radicals, , neutrals

- **Chacteristical time constants for production and loss of particles in plasma**

- **What do we measure with a mass spectrometer?**