

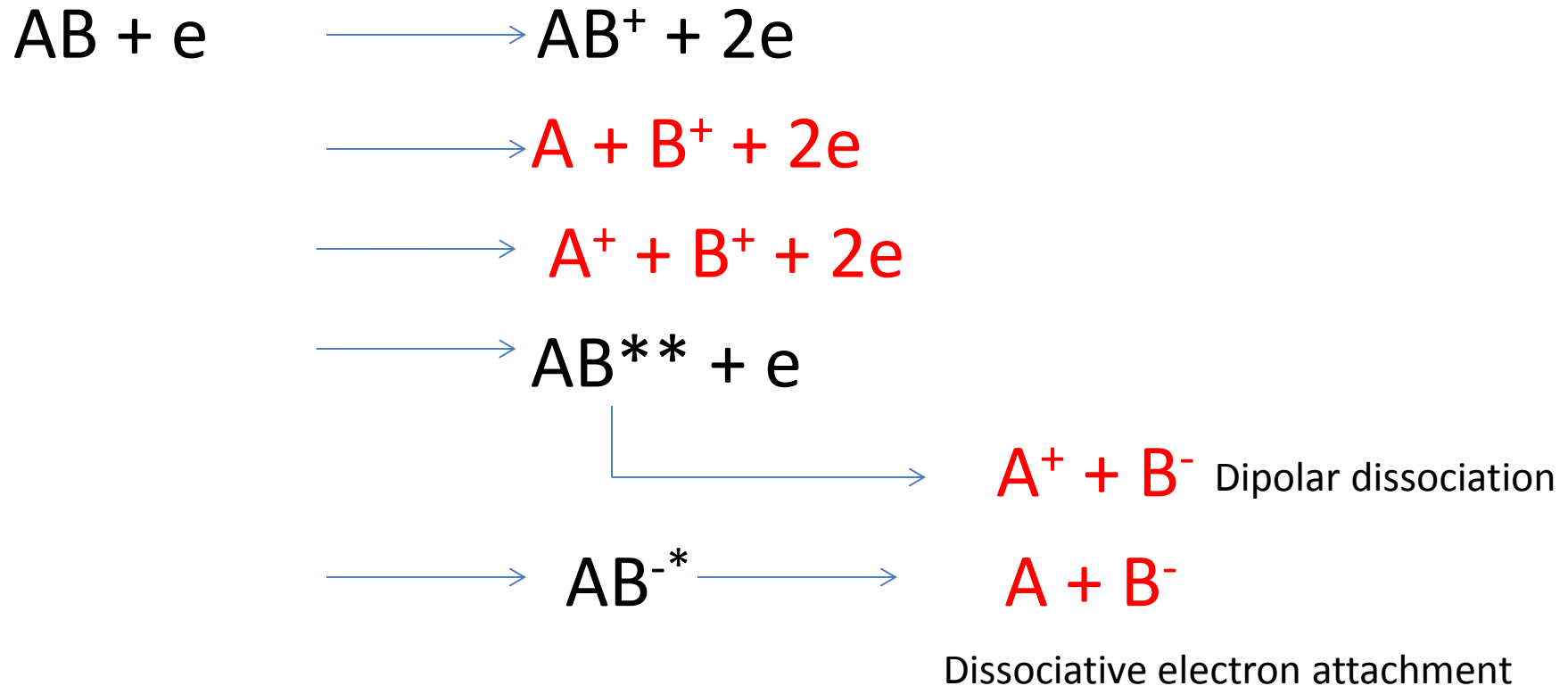
Absolute cross section measurements for dissociative electron ionization of and attachment to molecules

E. Krishnakumar

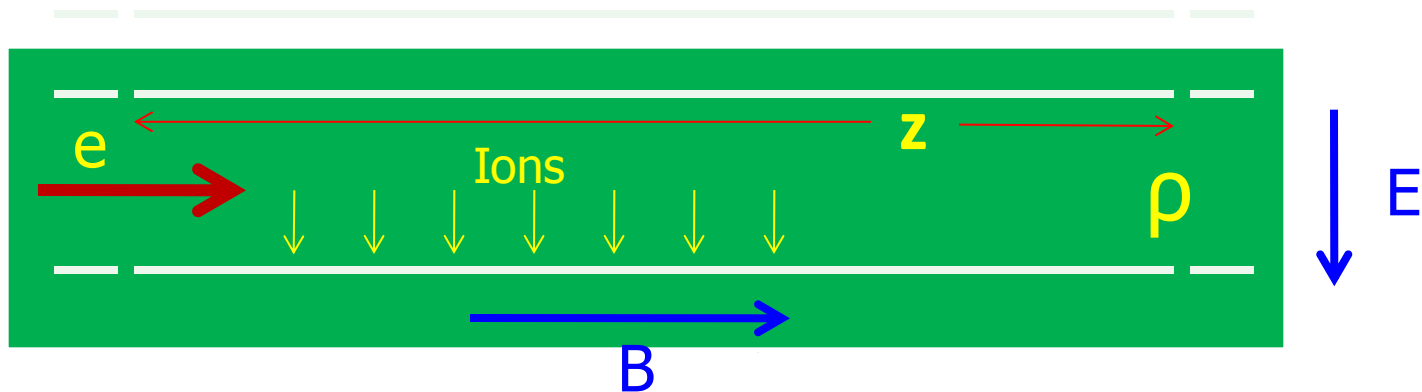
T I F R Mumbai

IAEA Meeting - Vienna 19 Dec. 2016

Ionization processes in molecules



Absolute cross section measurement

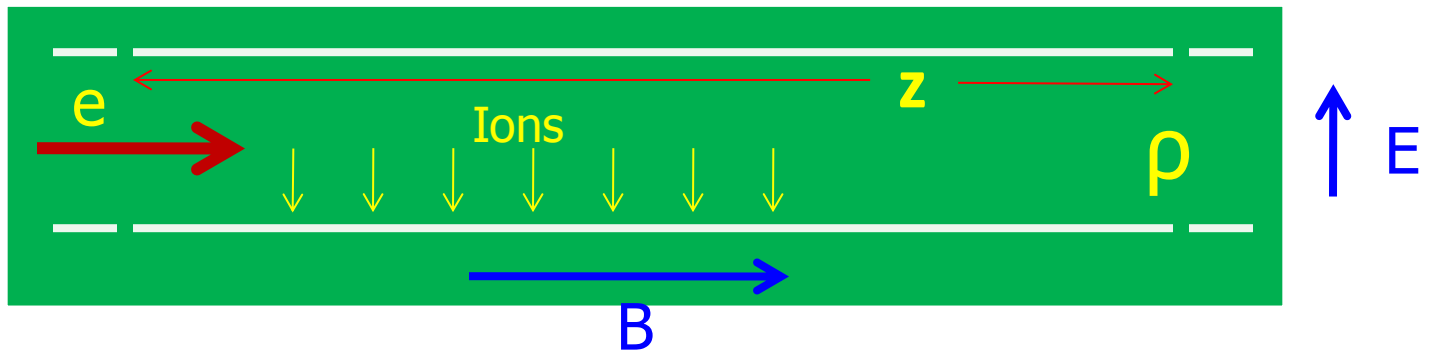


The total ion tube – Tate and Smith

$$I(\text{ion}) = \sigma(\text{total}) \cdot I_e \cdot \rho \cdot z$$

Uncertainty - 10 %

Dissociative ionization cross sections for H_2 , N_2 , O_2 using the total ion tube



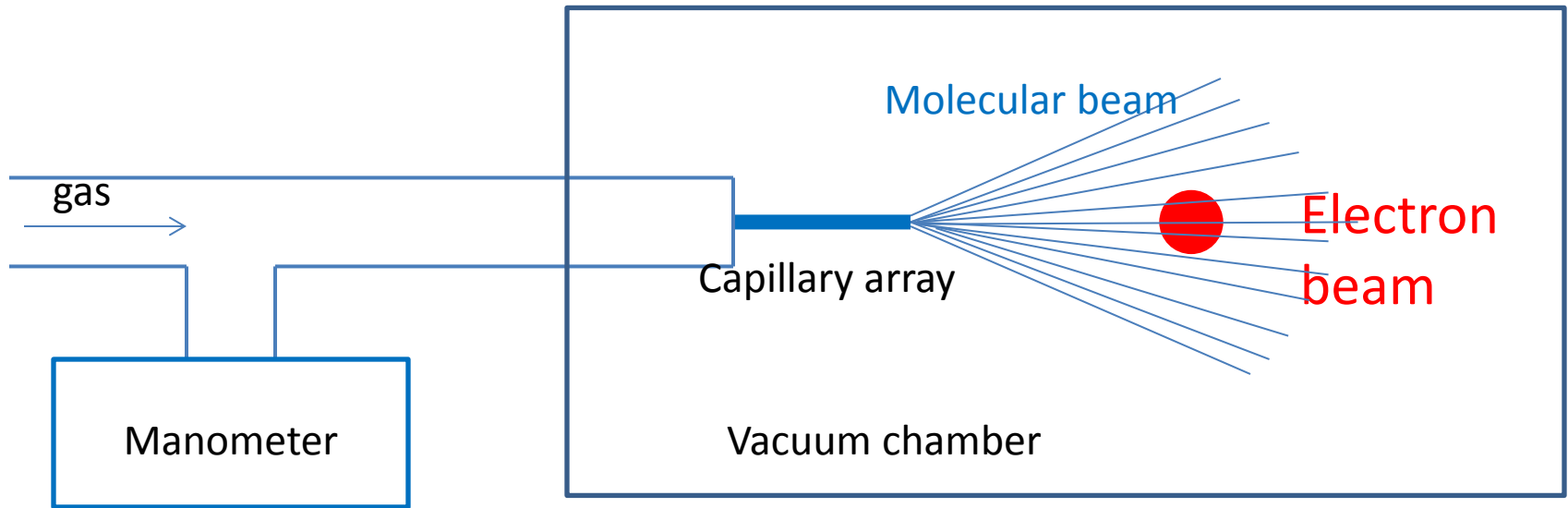
A reverse field is applied and only ions with enough kinetic energy to overcome that field is collected.

Geometric correction for the angular distribution is applied.

H^+ and D^+ ions above 2.5 eV were collected.

O^+ and N^+ ions above 0.5 eV were collected.

Relative flow technique



$$I(E_0) = K(m)\sigma(E_0) \int \rho(r) f_e(r, E_0) d\Omega(r) dr$$

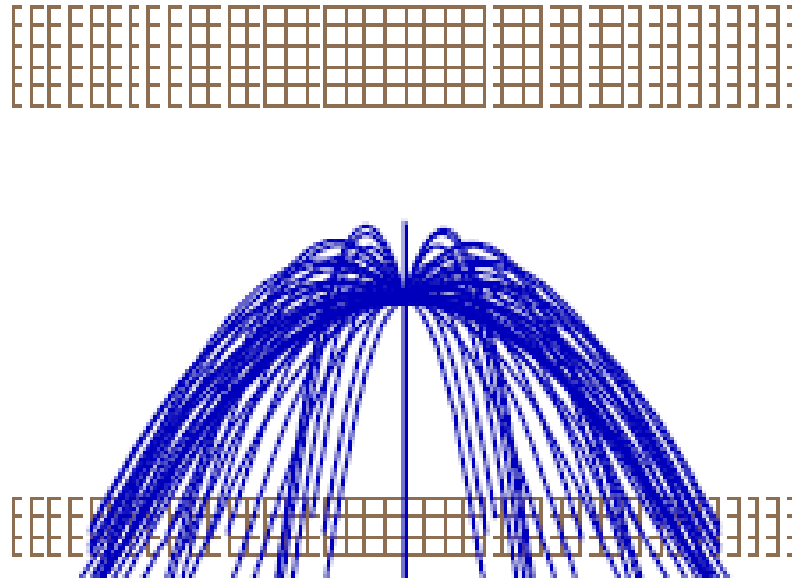
$$\sigma_u = \sigma_s \frac{N_u}{N_s} \frac{I_u^e}{I_s^e} \frac{F_s}{F_u} \left[\frac{M_s}{M_u} \right]^{1/2} \frac{K_u}{K_s}$$

Determination of K

$$\sigma_u = \sigma_s \frac{N_u}{N_s} \frac{I_u^e}{I_s^e} \frac{F_s}{F_u} \left[\frac{M_s}{M_u} \right]^{1/2} \frac{K_u}{K_s}$$

$$K = K_{\text{extraction}} K_{\text{transmission}} K_{\text{detection}}$$

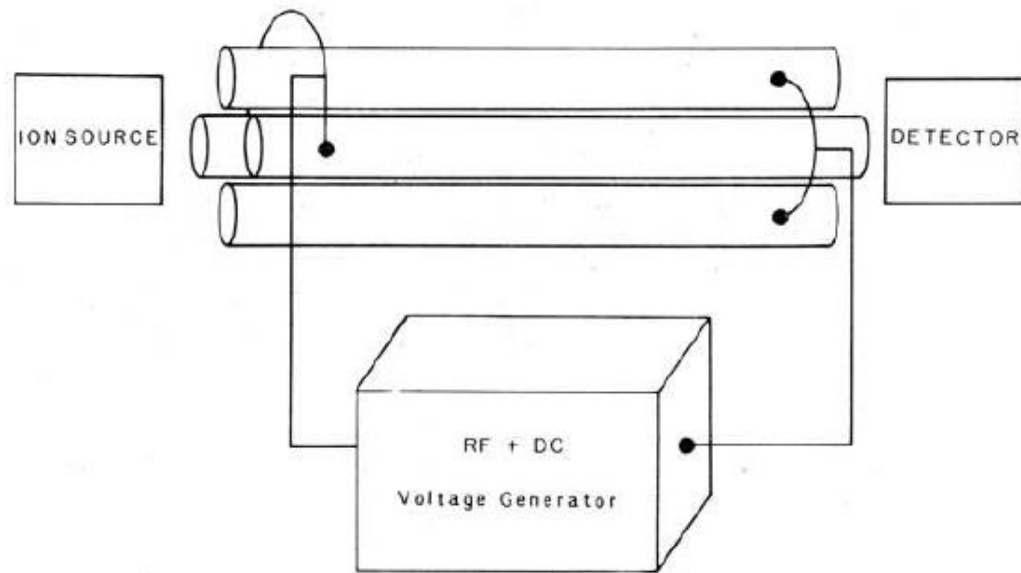
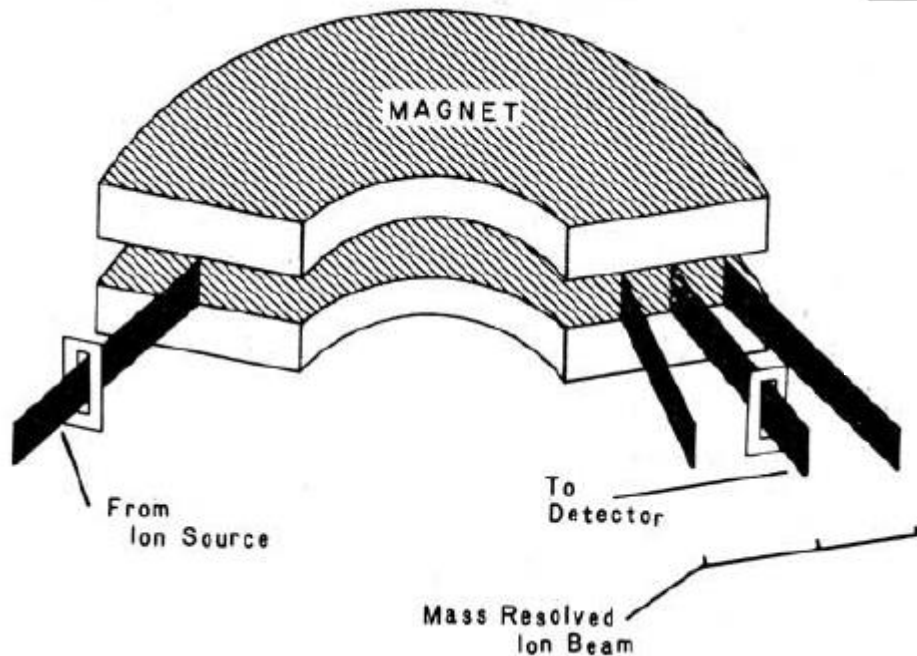
Energetic ion trajectories in E - field Extraction Problems ($K_{extraction}$)



1 eV ions, 5 V/cm extraction

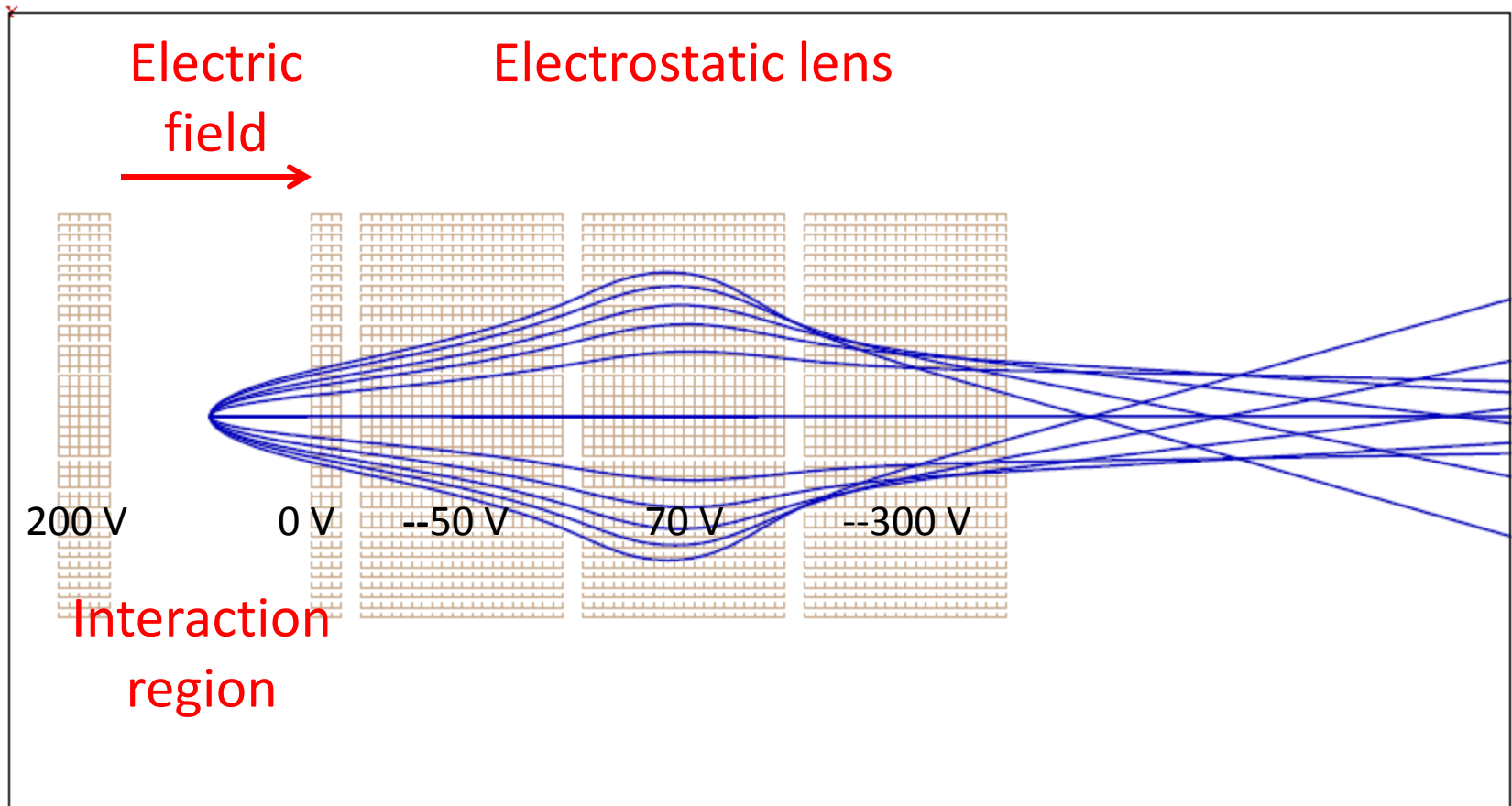
Problems with conventional mass analyzers ($K_{transmission}$)

Magnetic analyzer

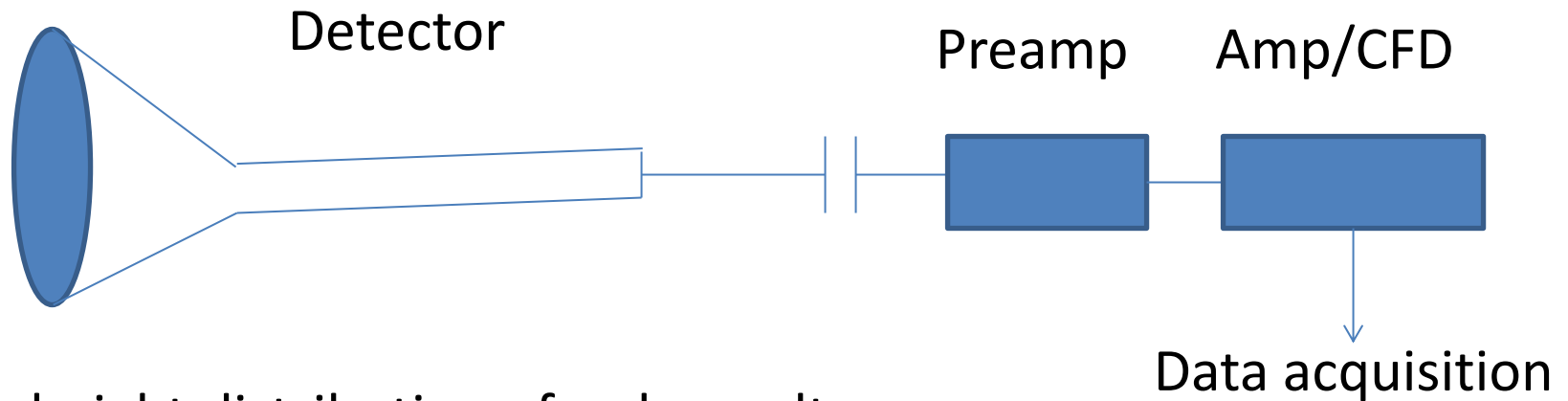


Quadrupole analyzer

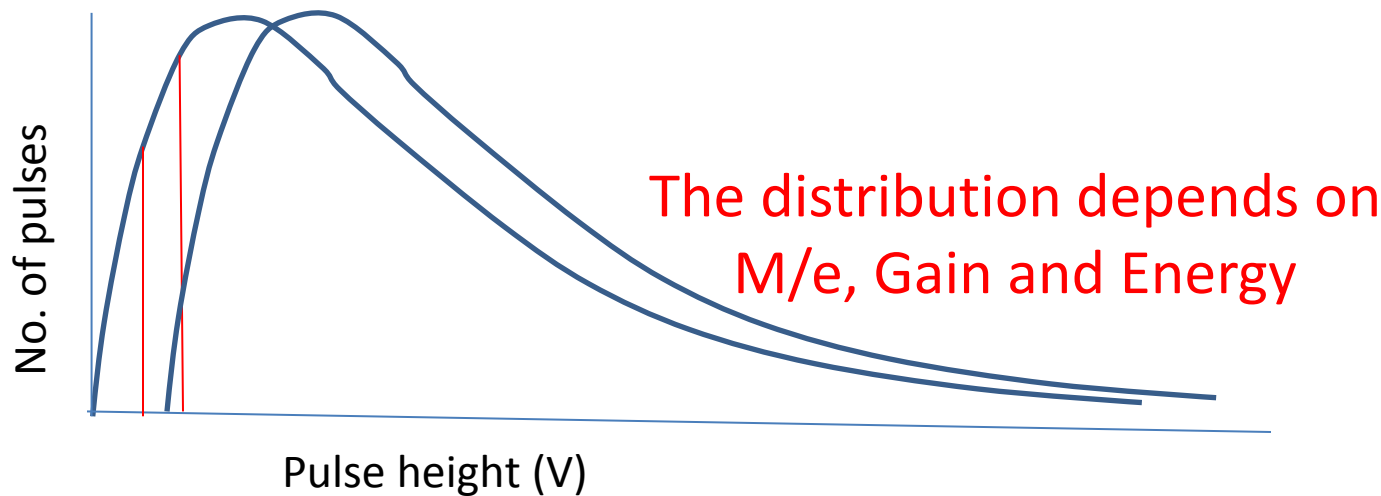
Extraction and focusing



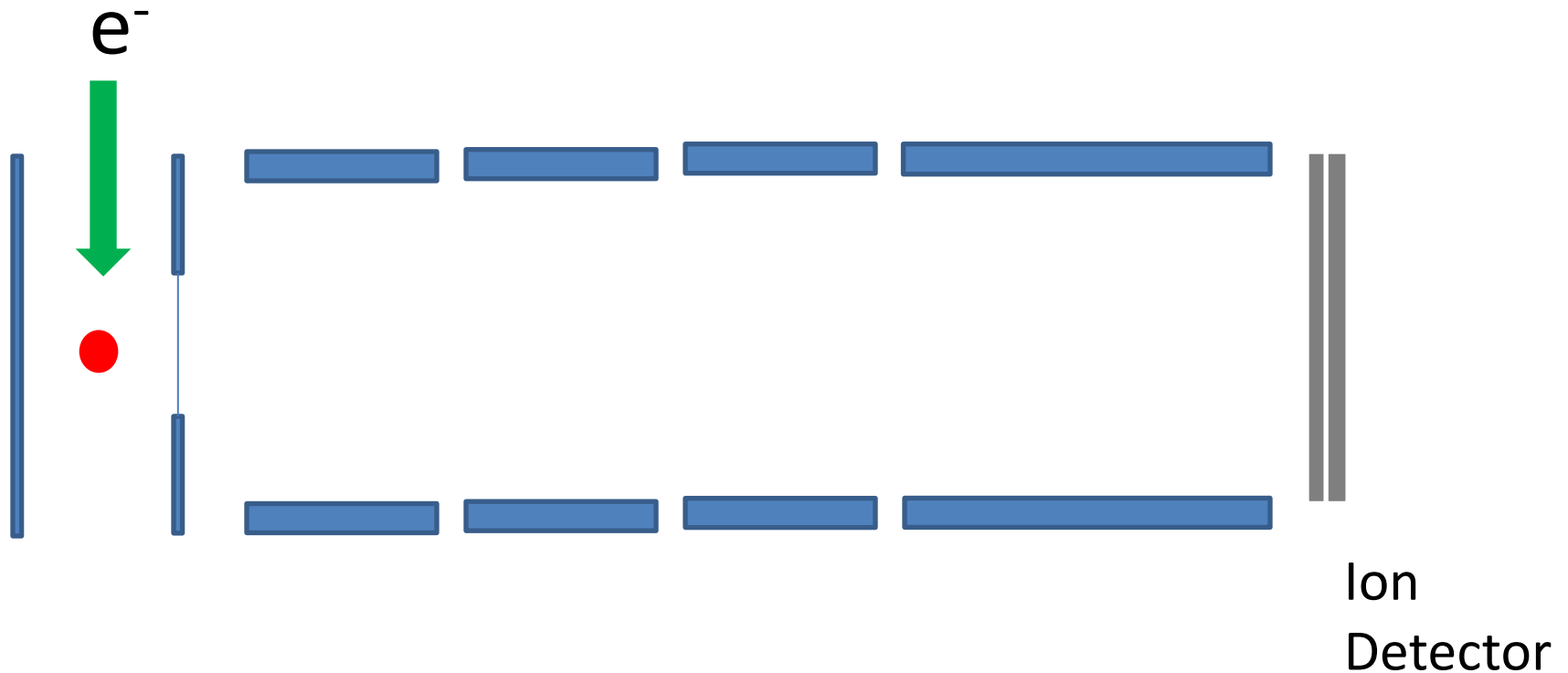
Detection efficiency ($K_{detection}$)



Pulse height distribution of a channeltron



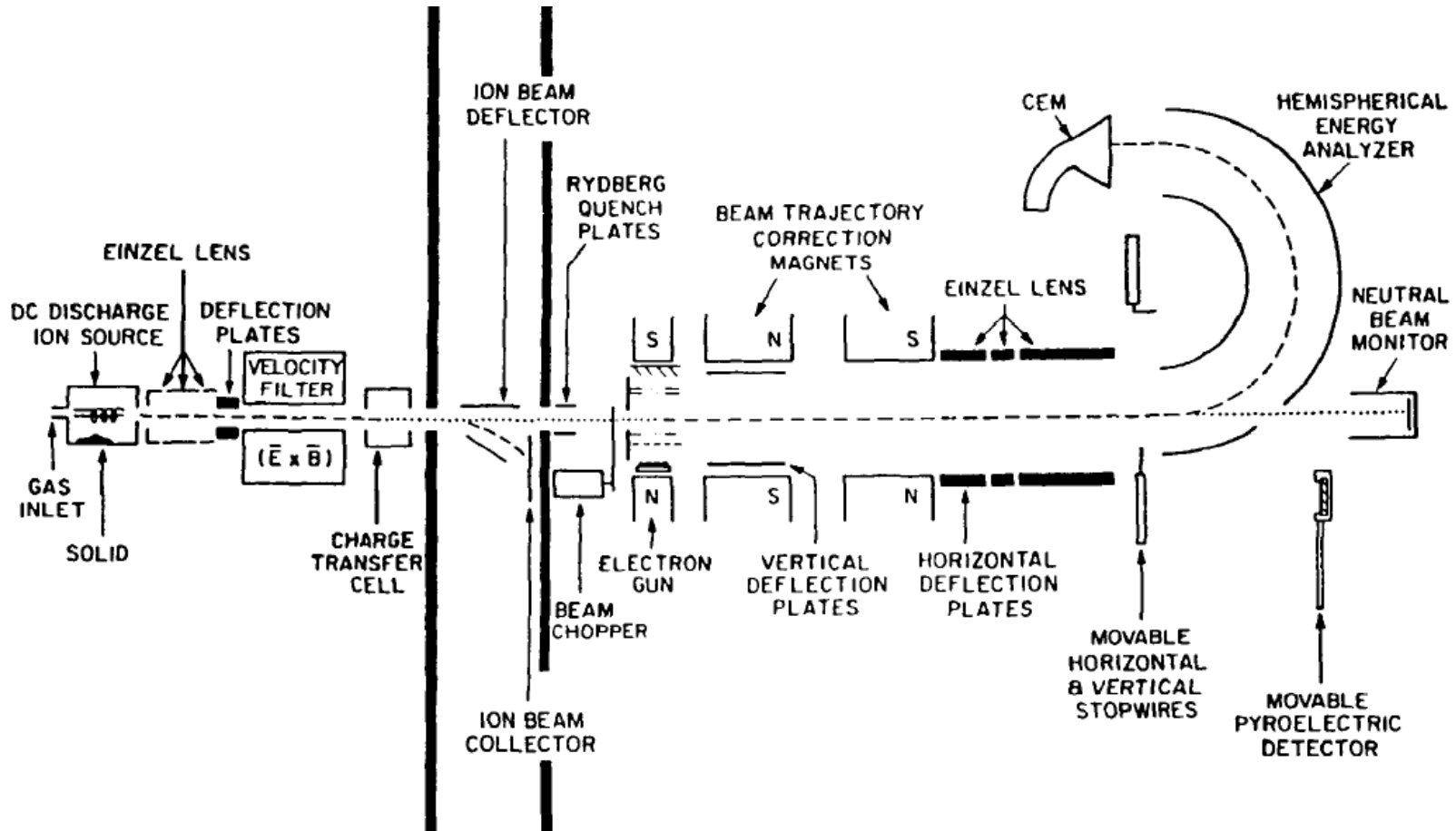
Segmented ToF mass spectrometer



- Pulsed electron beam
- Pulsed ion extraction

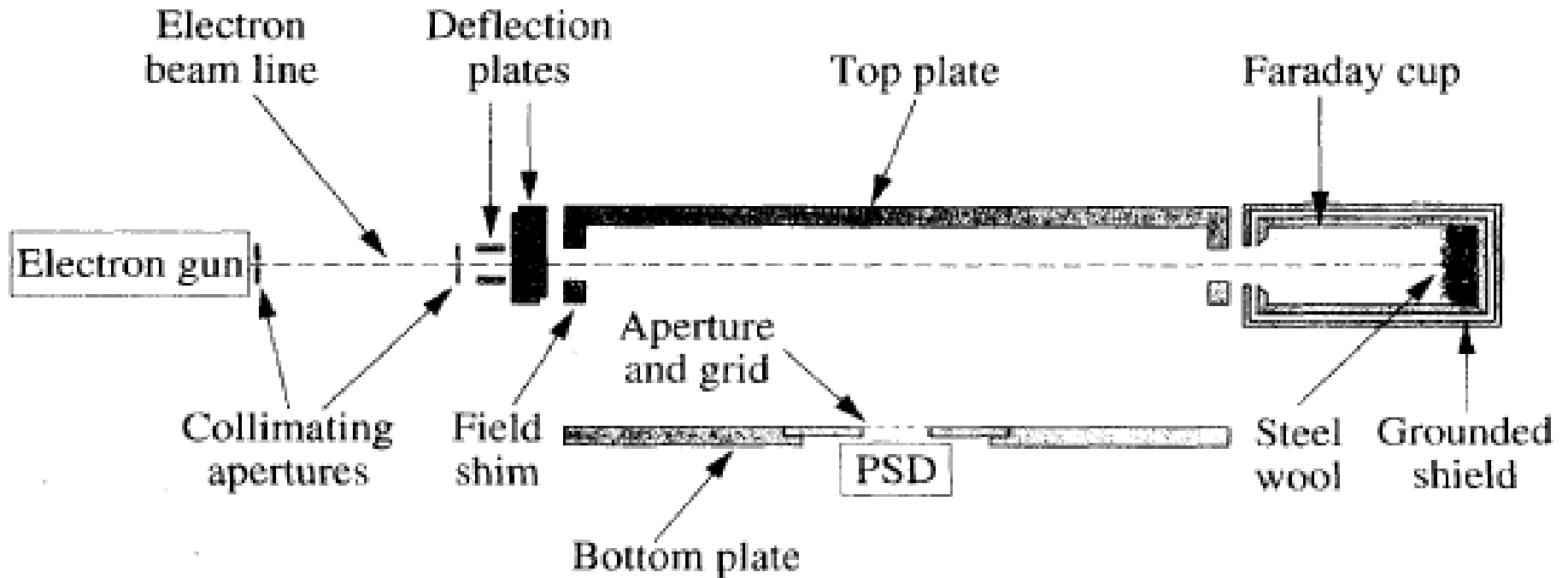
Typical uncertainty – 15 %
Dominated by uncertainty by the standard
data used.

Fast molecular beam technique



Mass separation based on the kinetic energy

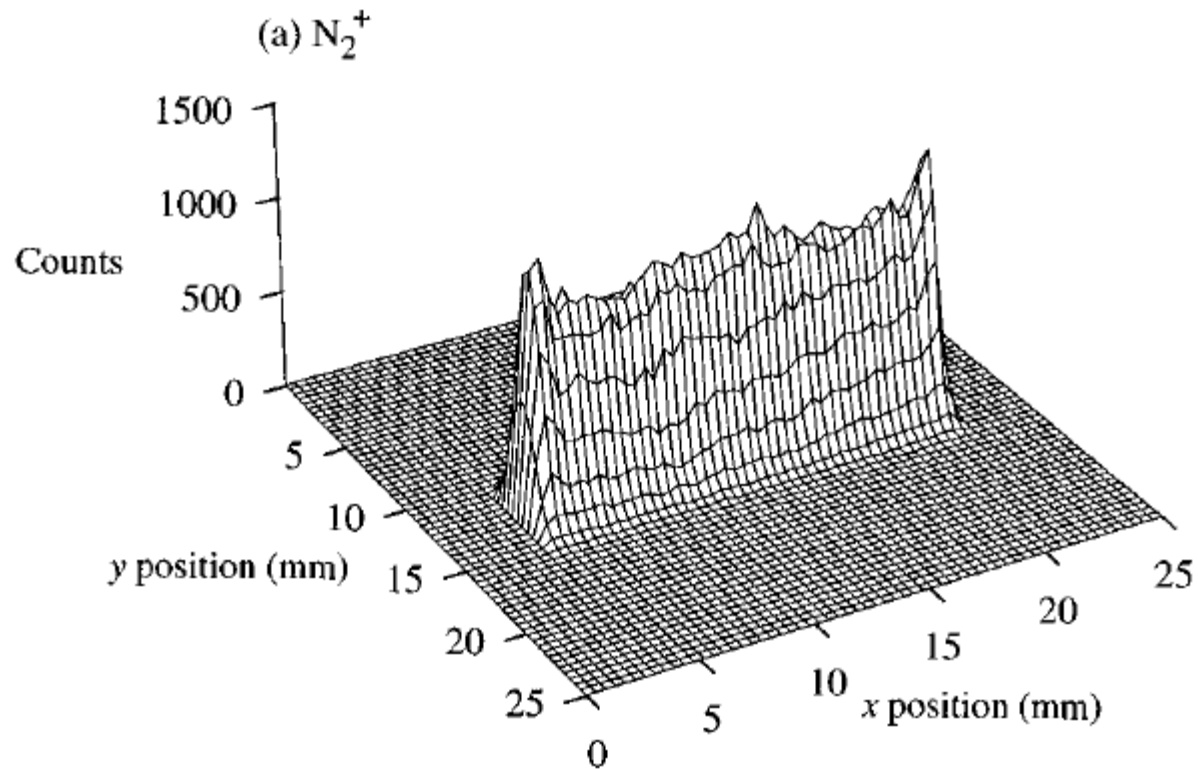
Modern total ion tube



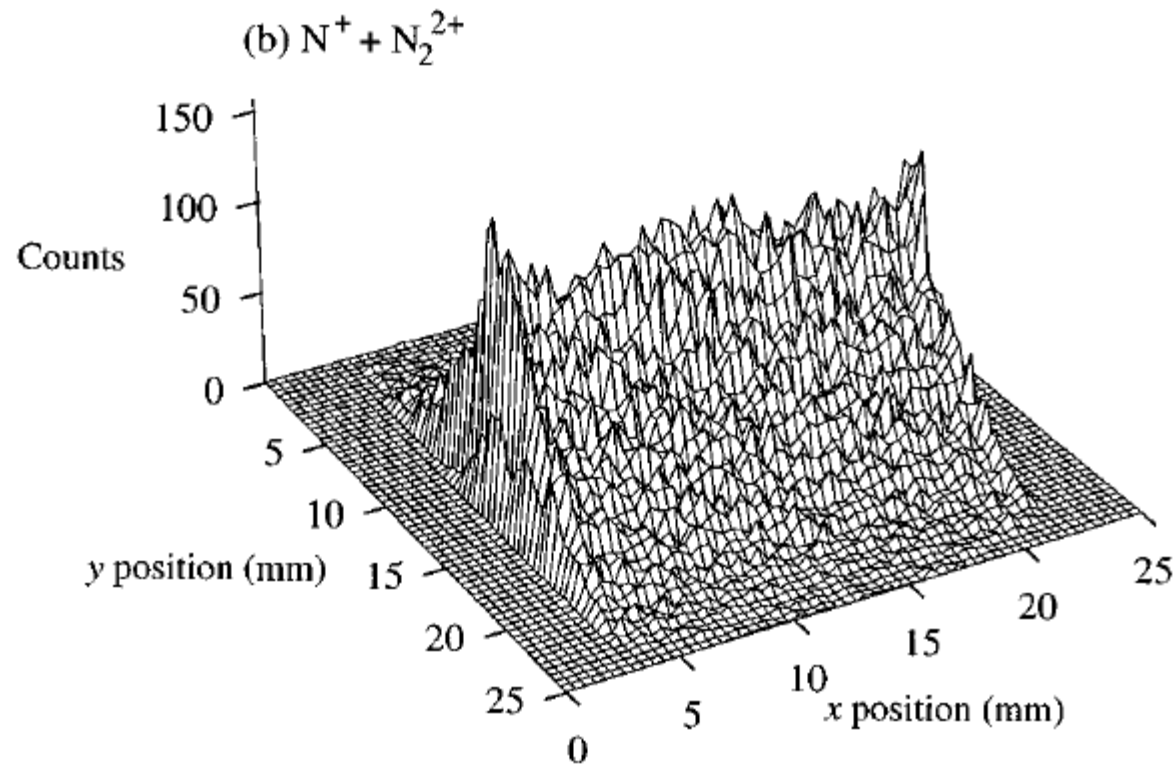
Uncertainty for Ar – 5%

Straub et al P R A 1995

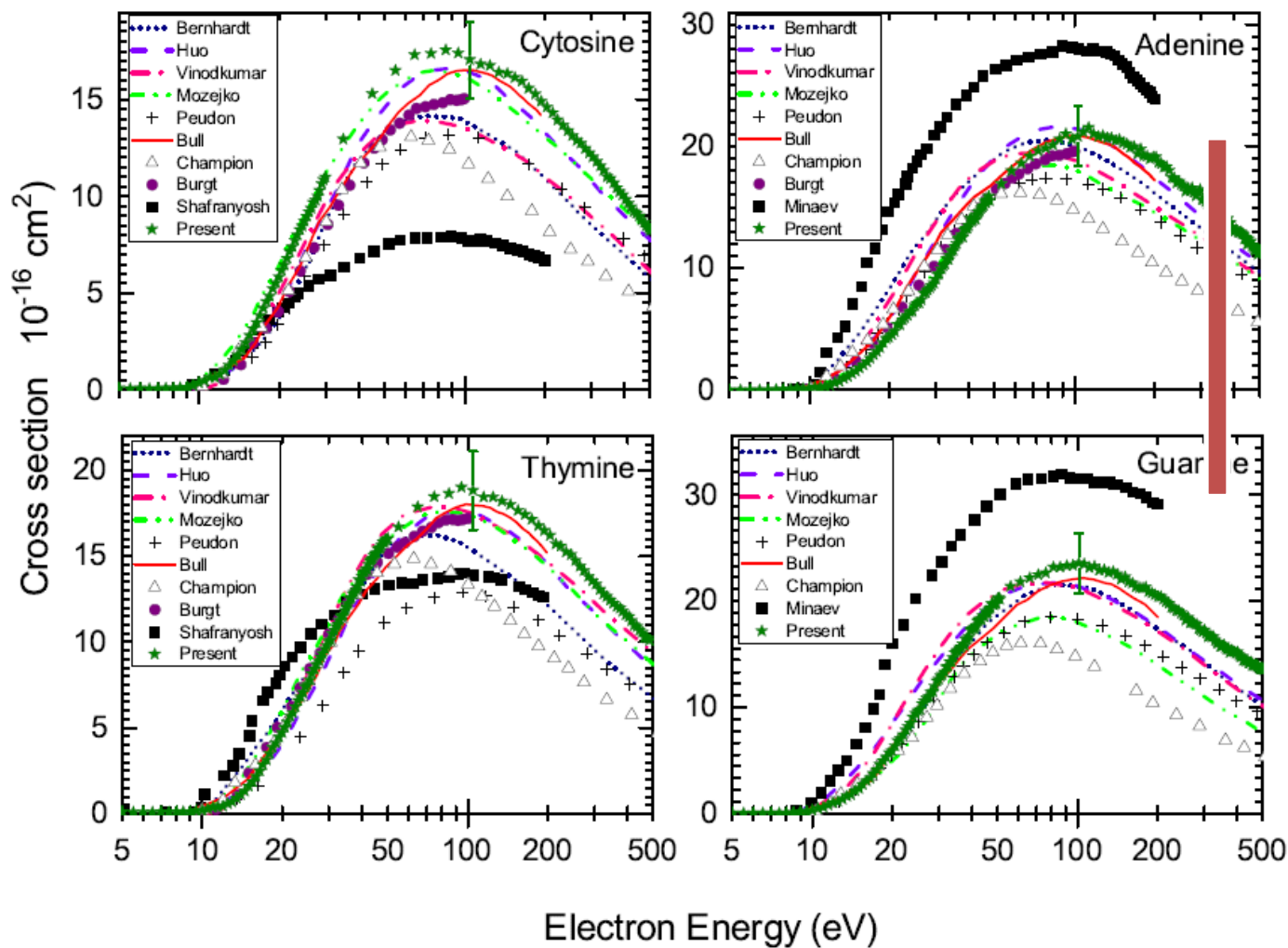
2D spatial image of the low parent ions



2D spatial image of the fragment ions



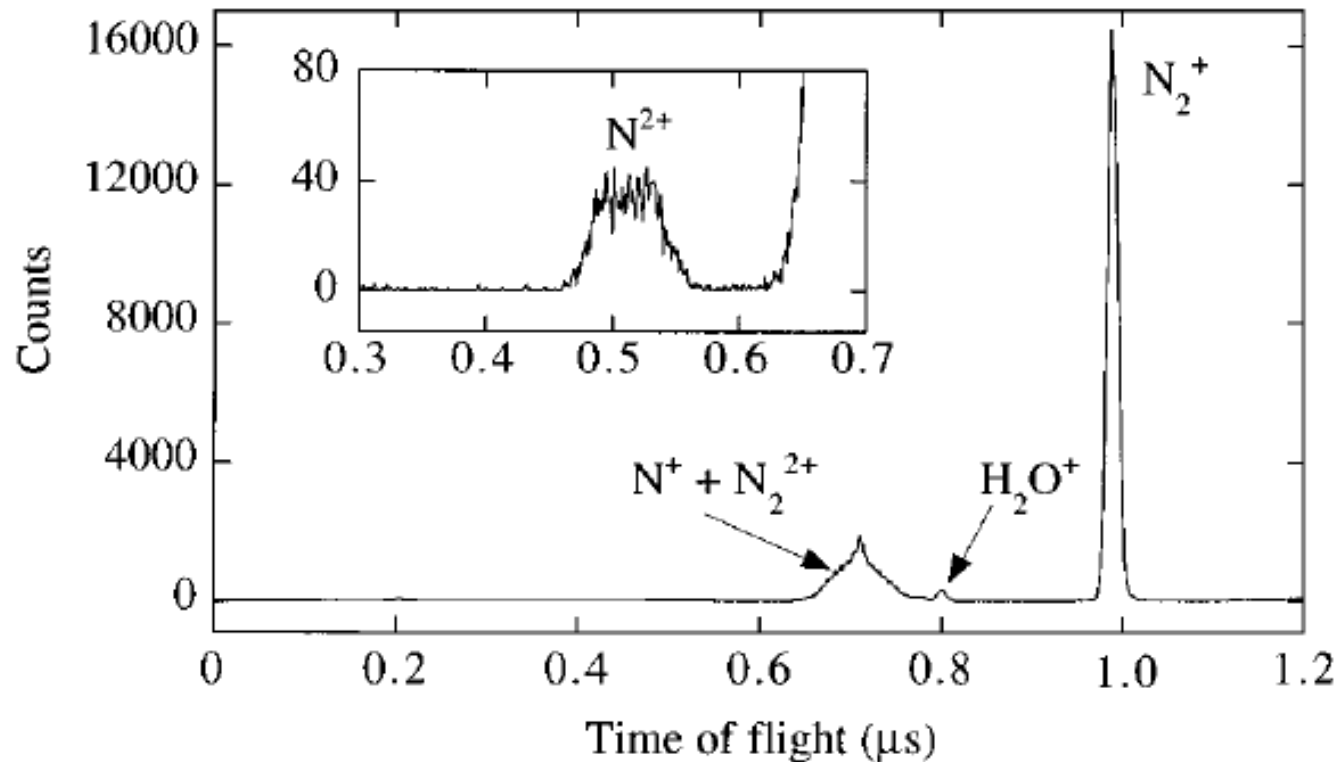
Extension of relative flow technique to solid samples



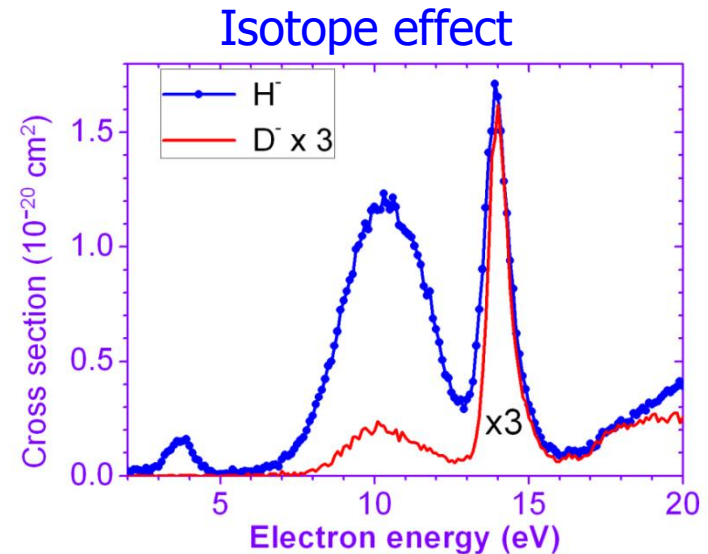
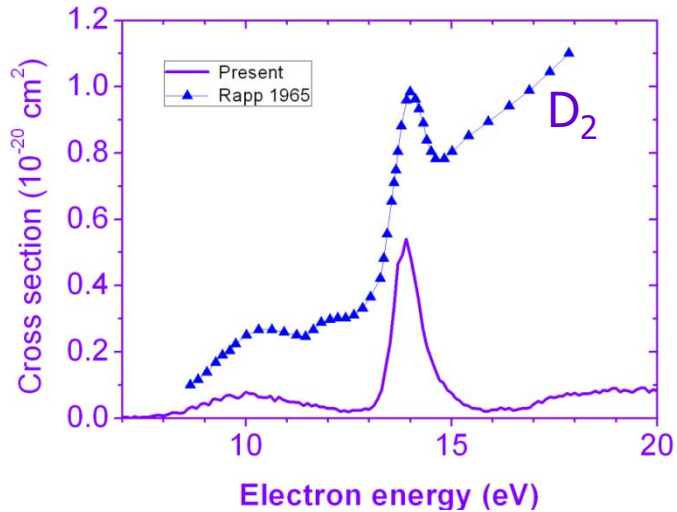
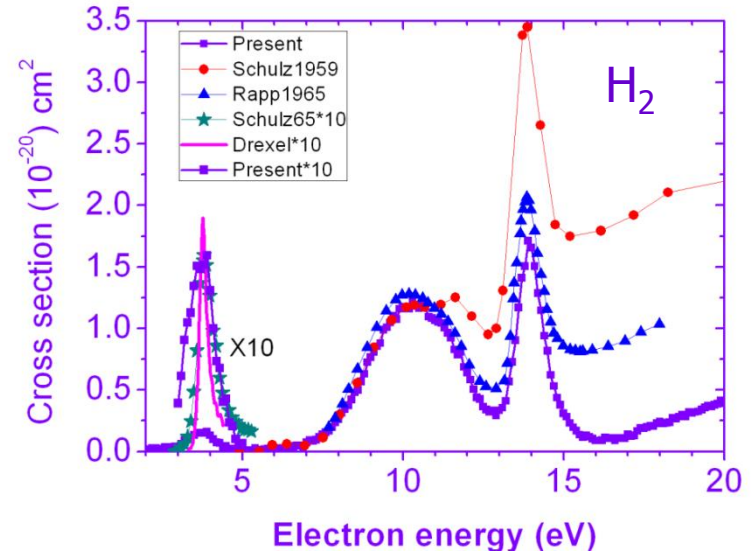
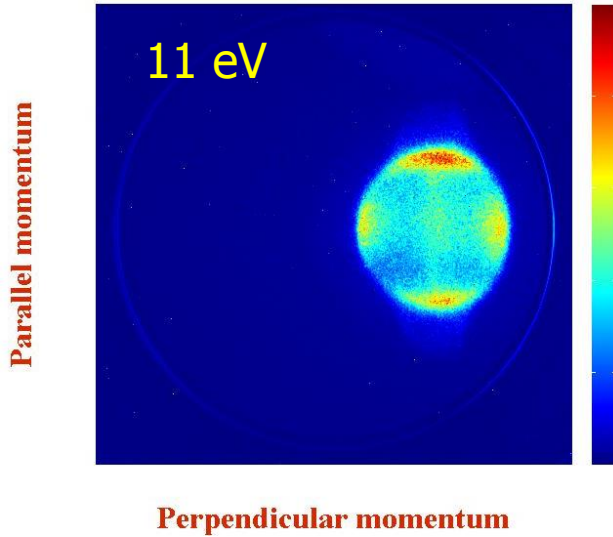
Uncertainty – 12 %

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Use of momentum imaging for absolute cross sections



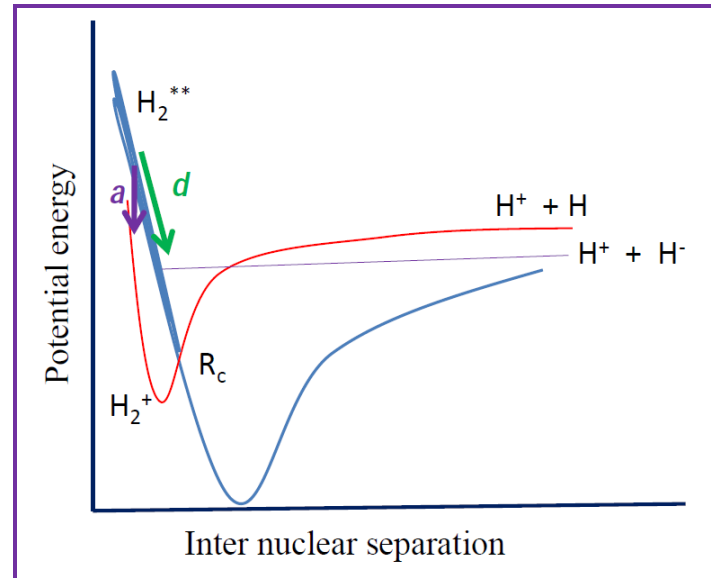
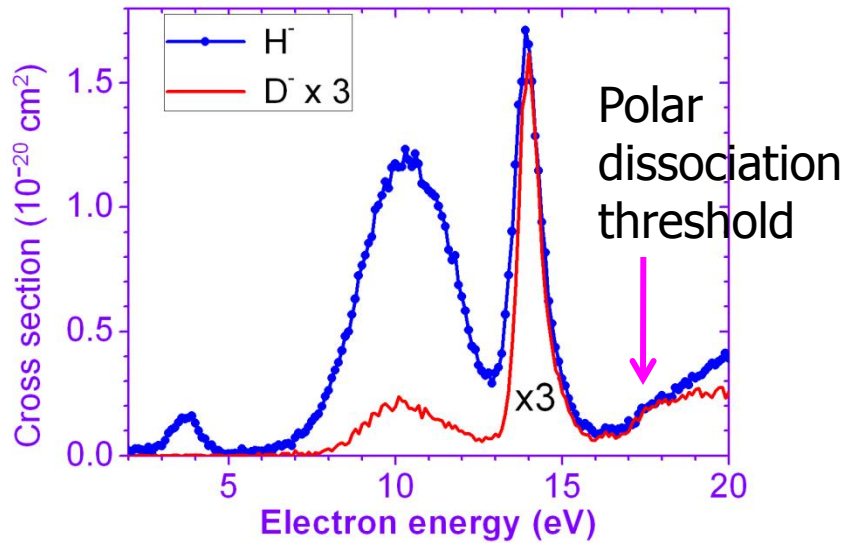
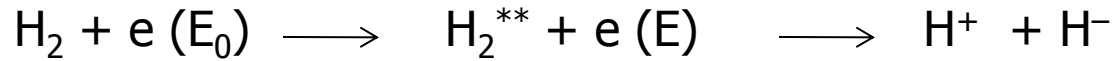
Absolute cross sections for DA in H₂ and D₂



Krishnakumar et al. PRL (2011)

Uncertainty – 12%

Polar dissociation and isotope effect



Very little information on these states.

Unlike other molecular states, have $1/r$ potential at large R . Recent studies (PRL 2008, JCP 2010) show them behave like "heavy Rydberg states" with a proton orbiting the negative ion.

Some Challenges

Cross sections for production of neutral

Cross sections from excited states – notably for DEA

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