Cluster ion size

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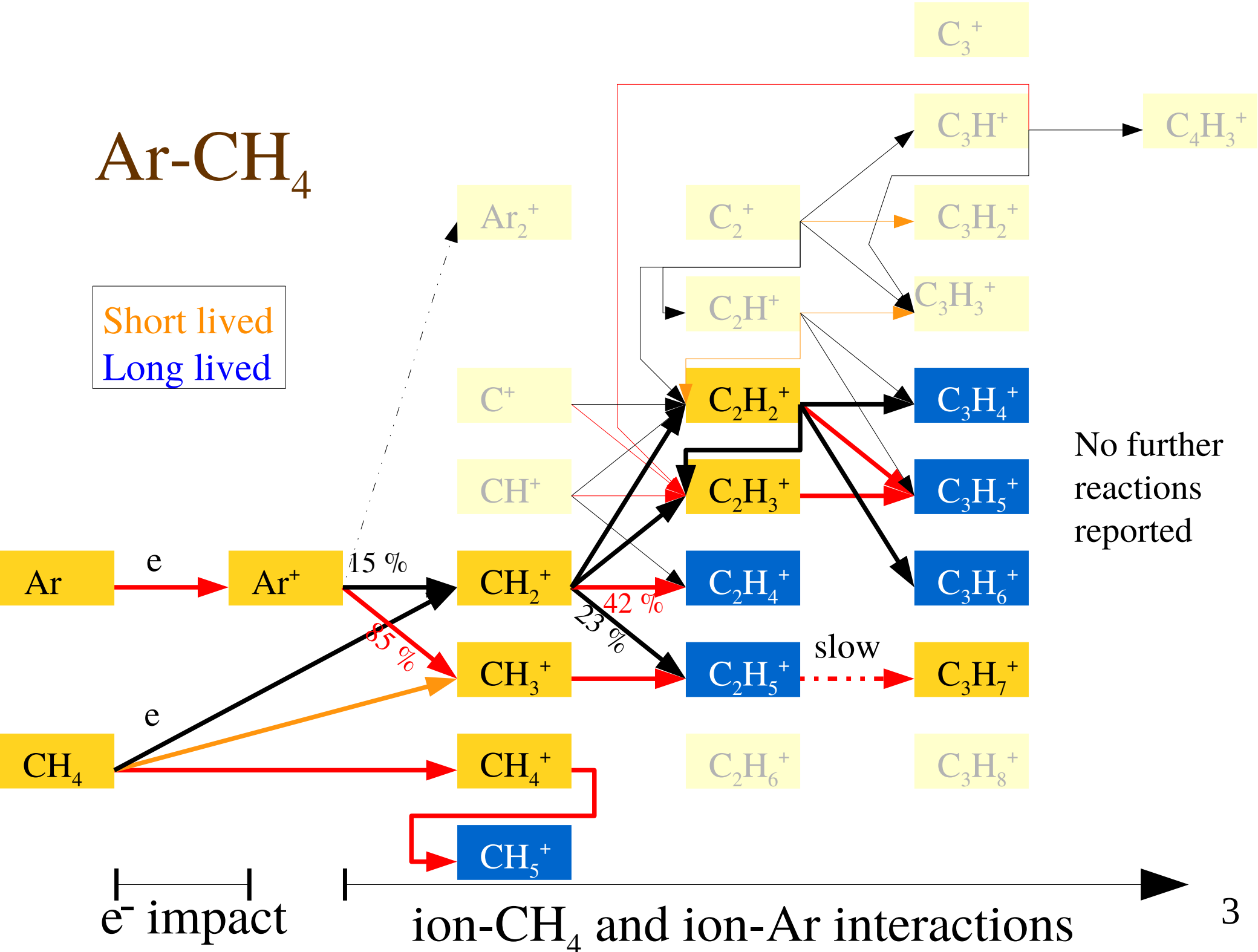
Reminding

- Alkane ions, noble gas ions and CO_2^+ react with the carrier gas to form molecular ions and cluster ions.
- Measurements of the ion mobility in Ar CO_2, Ne CO_2 and N_2CO_2 mixtures show that the ions are heavy, hence slow, so the signals induced by ion motion are altered.

[Y. Kalkan et al, “Cluster ions in gas-based detectors”, JINST 10 P07004, 2015.]

[Y. Kaya et al, “Protonated water clusters in TPC’s”, NIMA 824, 2016.]

Ar-CH_4

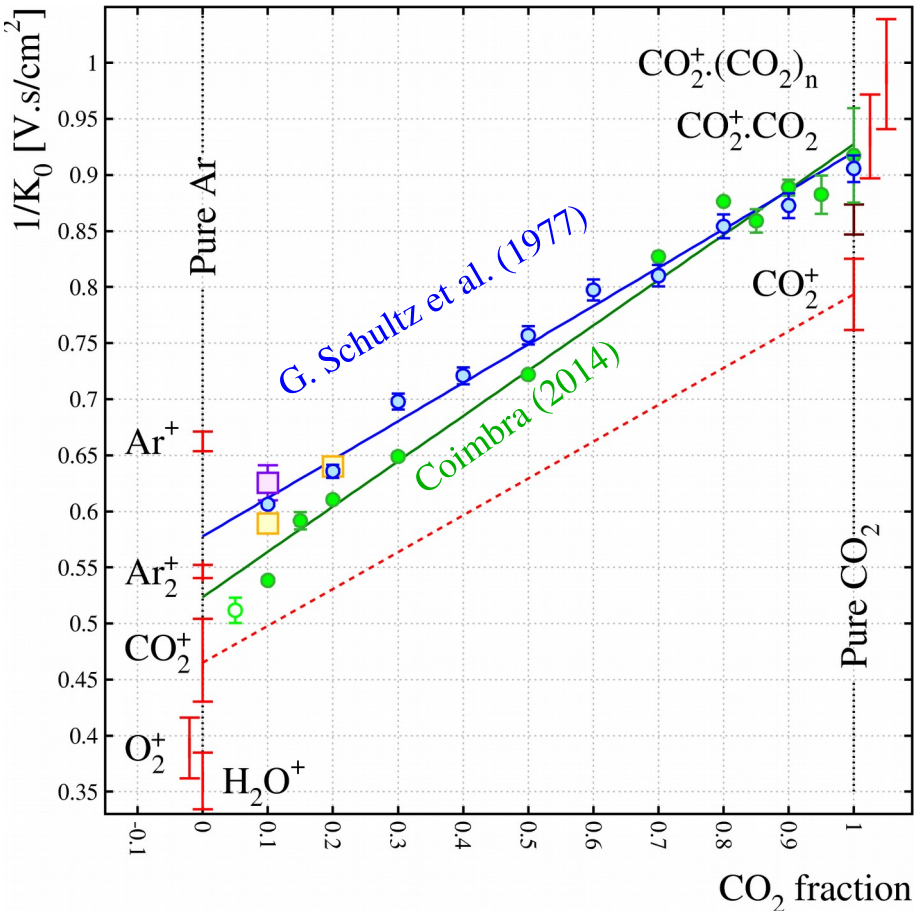

Short lived
Long lived
C_3^+
C_3H^+
$C_4H_3^+$
Ar_2^+
C_2^+
$C_3H_2^+$
C_2H^+
$C_3H_3^+$
C^+
$C_2H_2^+$
$C_3H_4^+$
CH^+
$C_2H_3^+$
$C_3H_5^+$
Ar
e
Ar^+
15 %
CH_2^+
$C_2H_4^+$
$C_3H_6^+$
42 %
23 %
85 %
CH_3^+
$C_2H_5^+$
slow
$C_3H_7^+$
e
CH_4
CH_4^+
$C_2H_6^+$
$C_3H_8^+$
CH_5^+
No further reactions reported
e^- impact
ion-CH_4 and ion-Ar interactions

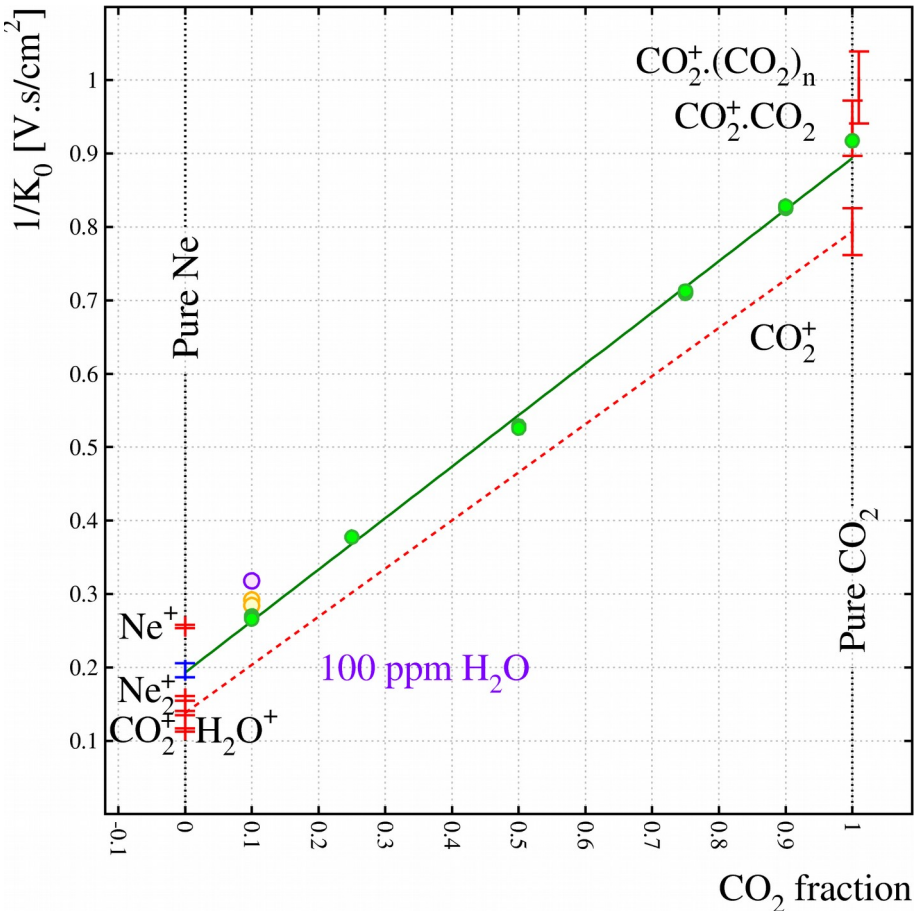
Clustering reactions involving CO_2

- Ar^+: charge exchange, $\tau \approx 0.85$ ns
  - $Ar^+ + CO_2 \rightarrow Ar + CO_2^+$
- Ne^+: charge transfer in 2steps, $\tau \approx 8$ ns
  - $Ne^+ + CO_2 \rightarrow Ne + CO^+ + O$
  - $CO^+ + CO_2 \rightarrow CO + CO_2^+$
- CO_2: 3body association, $\tau = 0.72.0$ ns (faster if Ar helps)
  - $CO_2^+ + 2CO_2 \rightarrow CO_2^+ \bullet CO_2 + CO_2$
- [For 10 % CO_2, atmospheric pressure, room temperature]

Ions drifting in Ar-CO_2 and Ne-CO_2

- Little Ar^+, Ne^+, CO_2^+ but $CO_2^+ \bullet (CO_2)_n$





Technique: Rayleigh (or Mie?) scattering

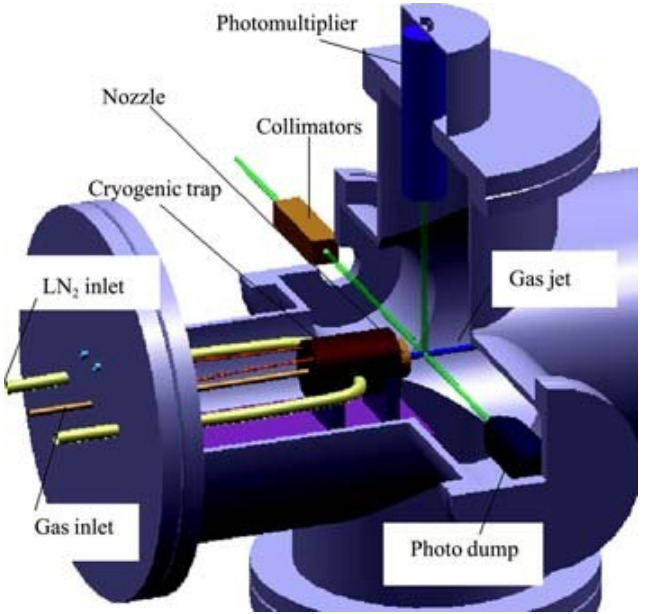
- Frequently used for the size determination

  [Lei An-Le et al, 2000, Chinese Phys. Lett., 17 661]
  [Li Shao-Hui et al 2003 Chinese Phys. 12 856]
  [Liu Bing-Chen et al 2002 Chinese Phys. Lett. 19 659] and more...

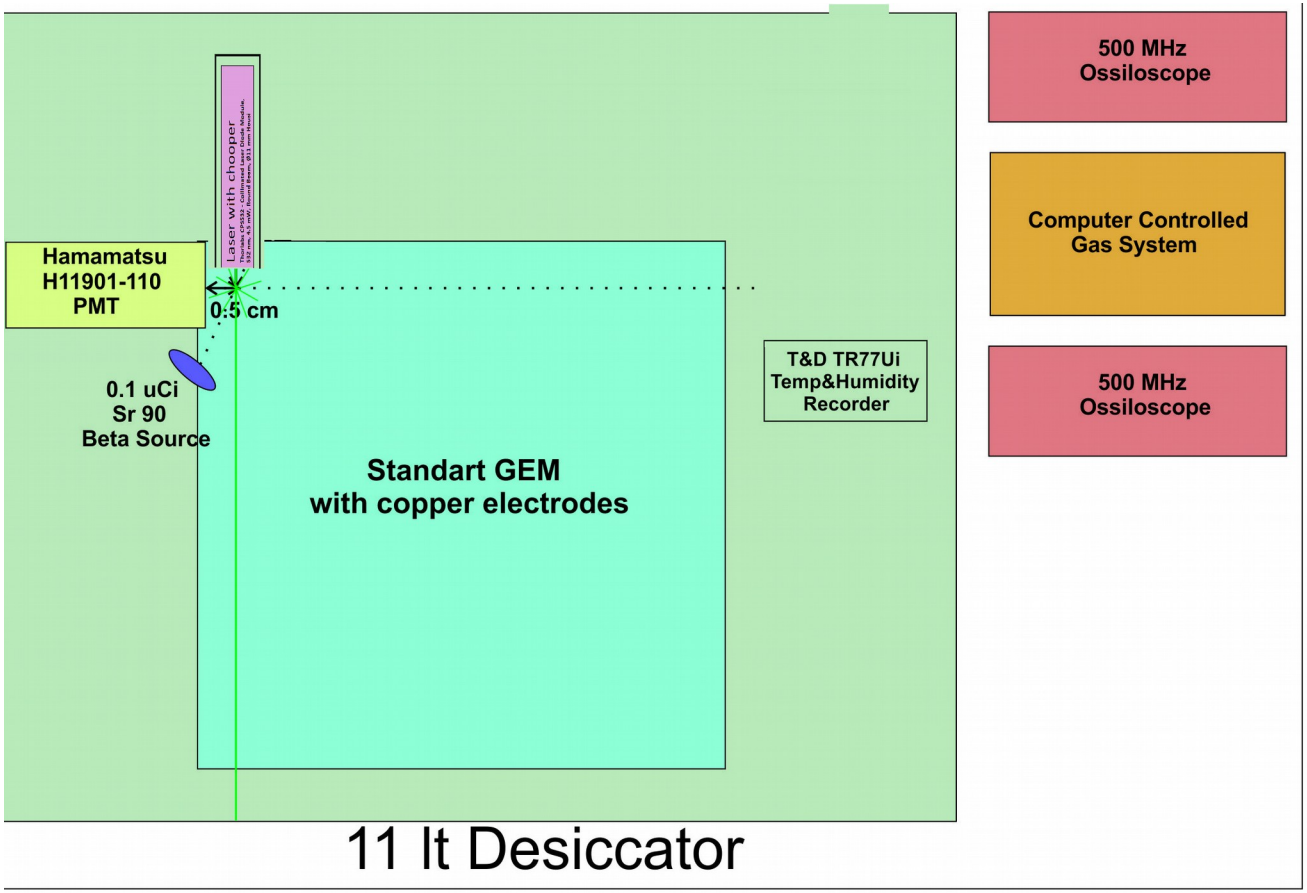
- Clusters produced in the process of adiabatic expansion

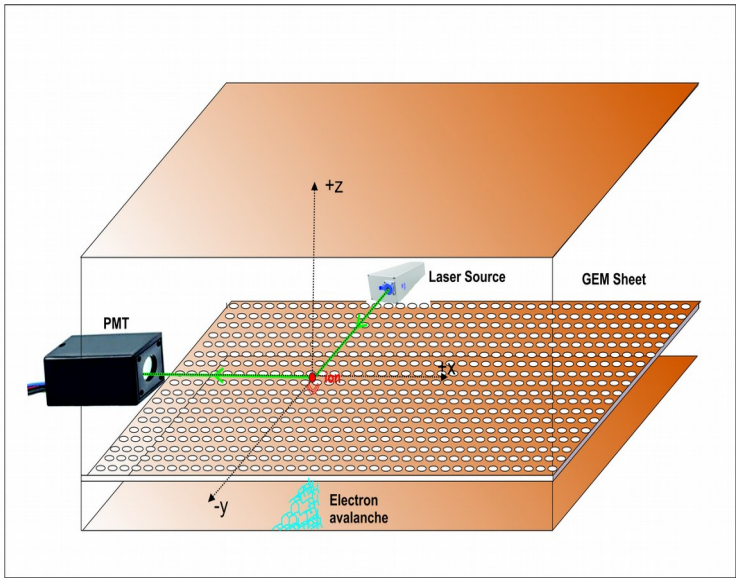
- 100 to more than 12000 atoms/cluster with the argon gas

- at 3 to 45 atm and room temperature

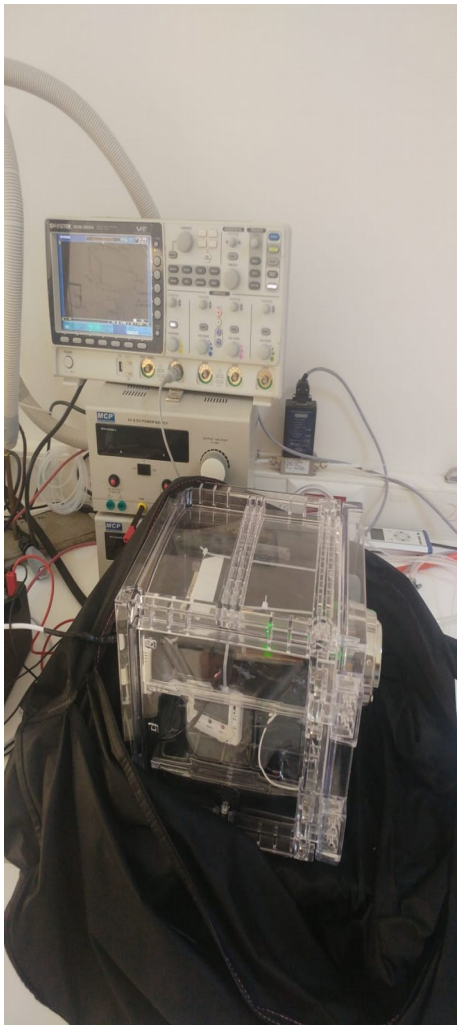


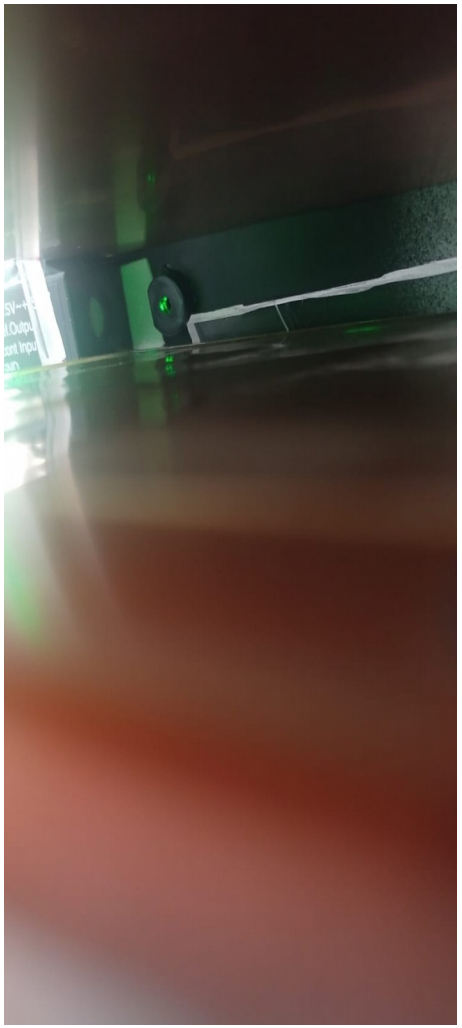
Experimental setup schema



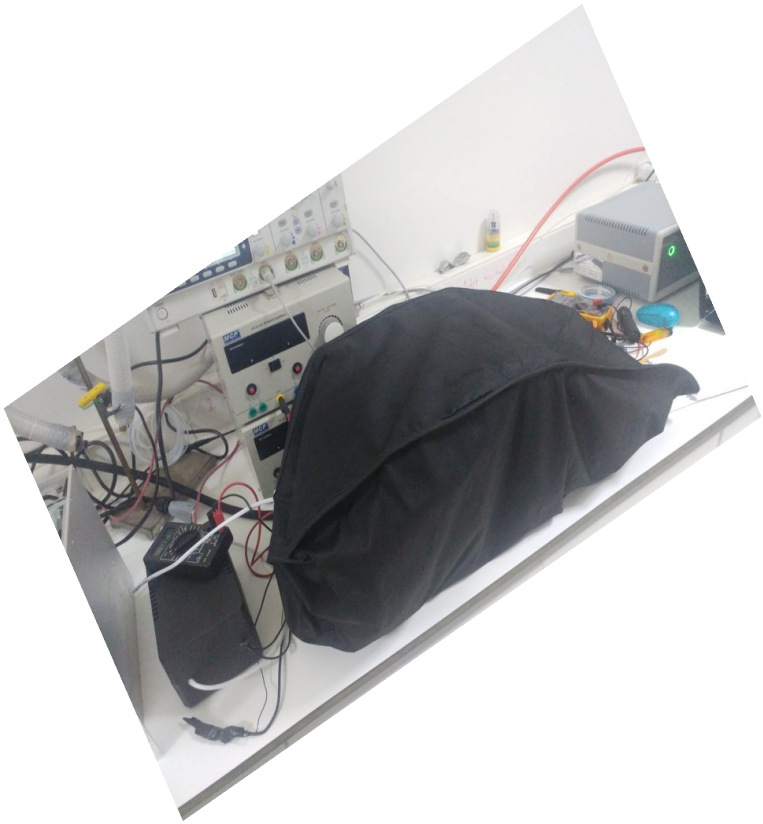


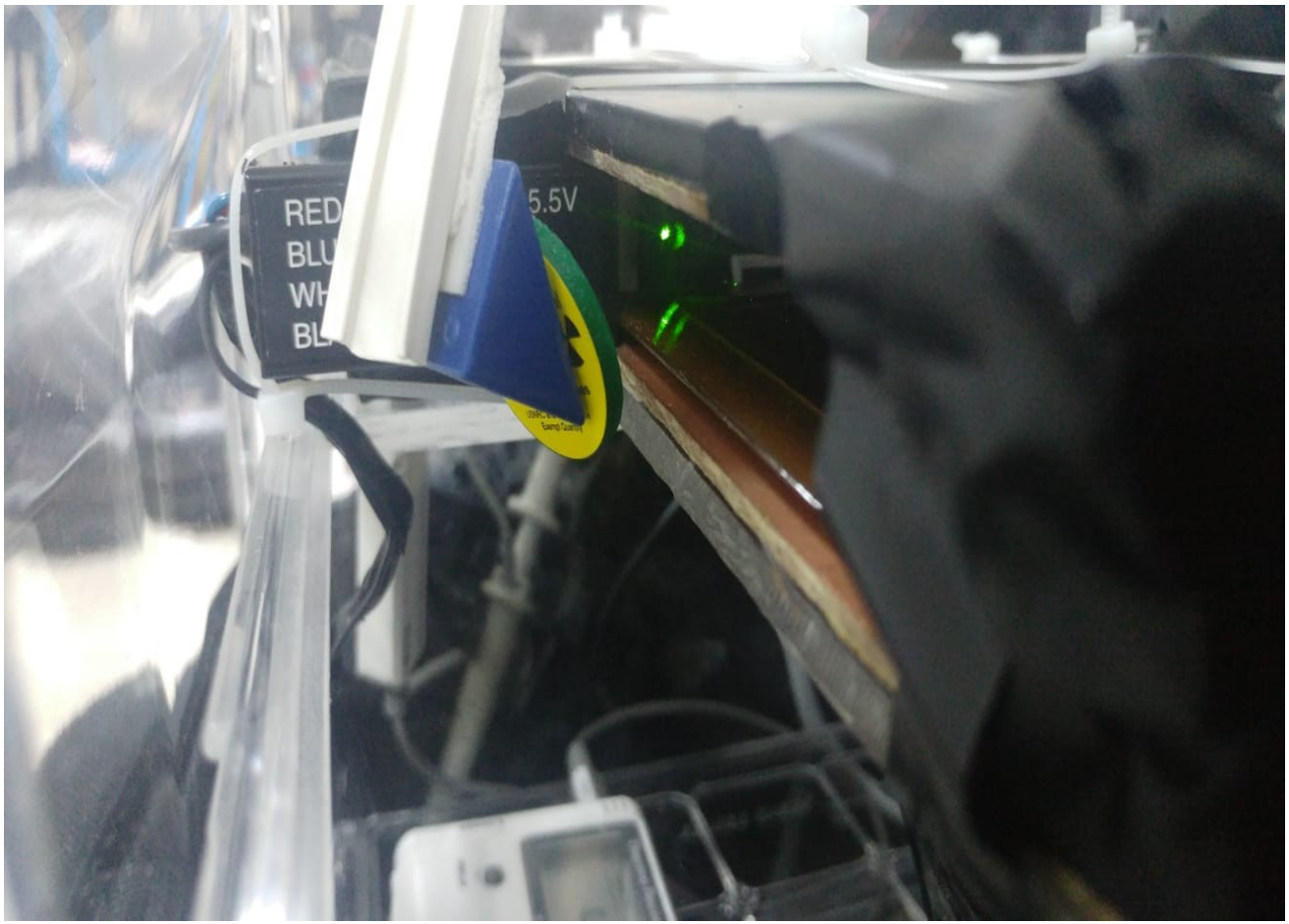
Experimental setup





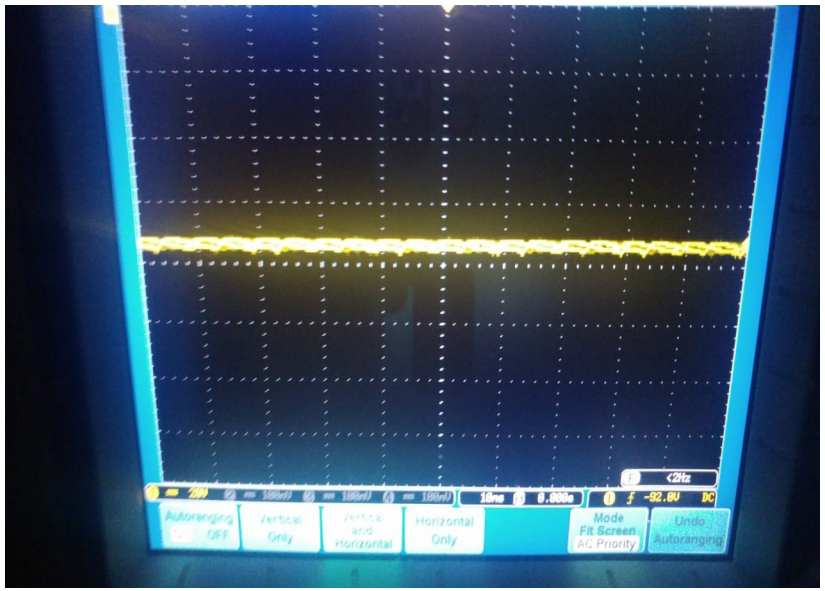
Experimental setup



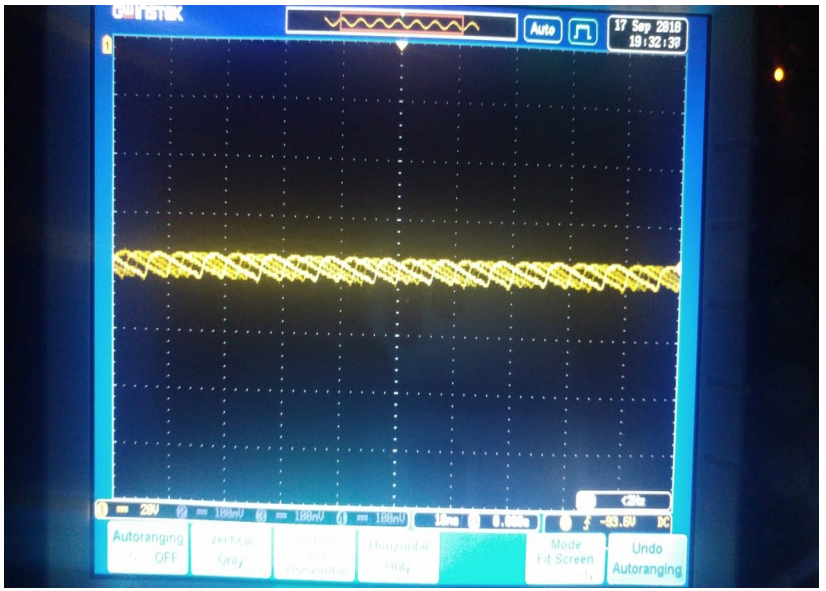


System control

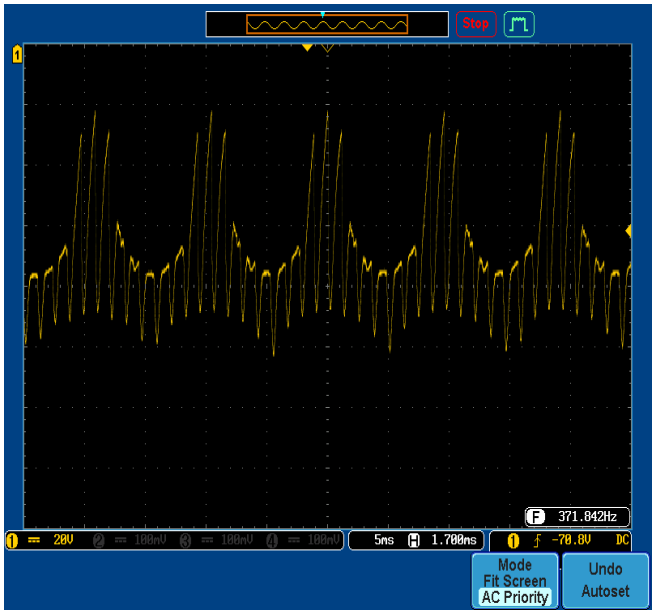
Laser OFF Gas ON



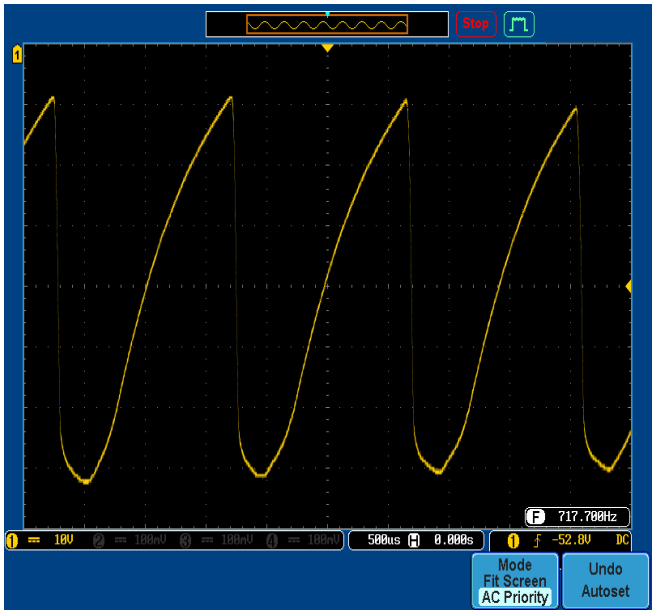
Laser ON Gas OFF (in -0.8 Atm Vac.)



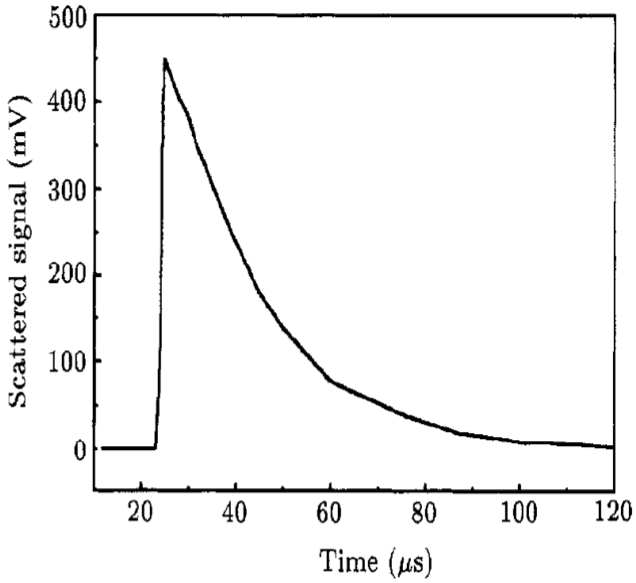
Scattered signal shape



Full Argon



Mixture

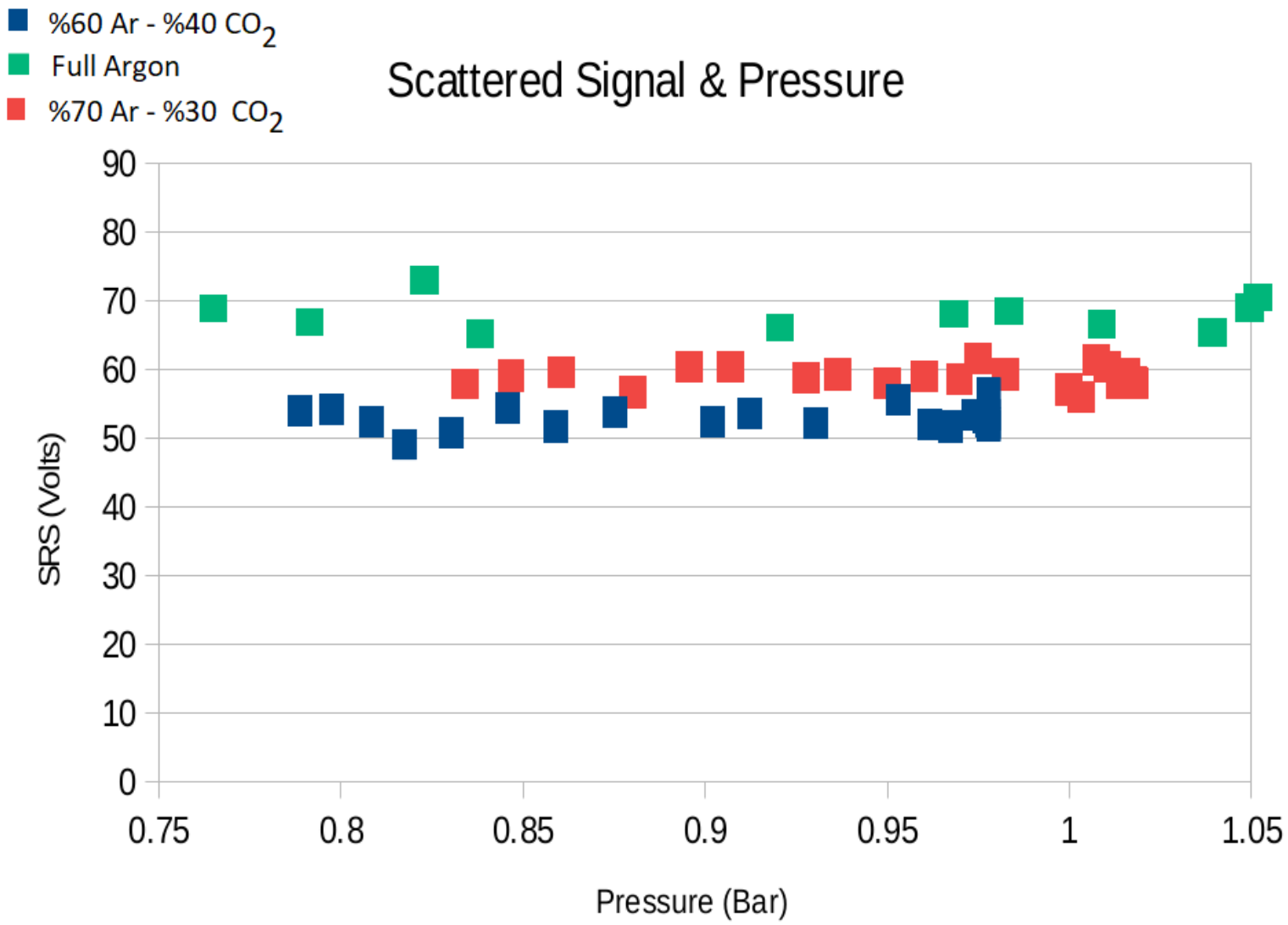


Lee's signal

Press: ~14 Atm,
Room temp.,
%100 Ar ions

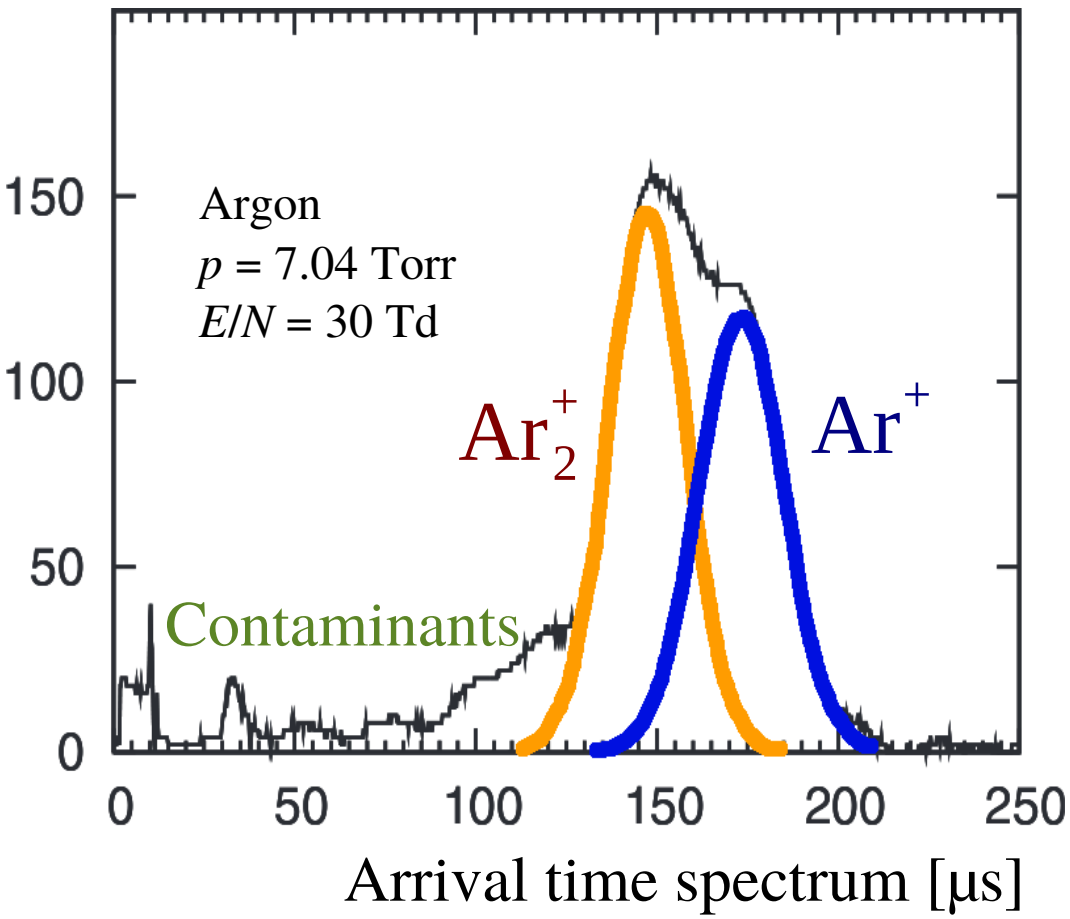
(Lei An-Le *et al* 2000 *Chinese Phys. Lett.* **17** 661)

First findings



Ions drifting in pure Ar

- In pure argon, dimers are formed:
  - $Ar^+(^2P^o_{3/2}) + 2Ar \rightarrow Ar^+ \bullet Ar + Ar$ ($k = 2.3 \pm 0.1\ 10^{31}$ cm^6/s)
  - Note: dimers are faster than ions due to $Ar \leftrightarrow Ar^+$ resonant charge exchange
- In mixtures, charge exchange dominates:
  - $Ar^+ + CO_2 \rightarrow Ar + CO_2^+$ ($k = 4.2\ 10^{10}$ cm^3/s)



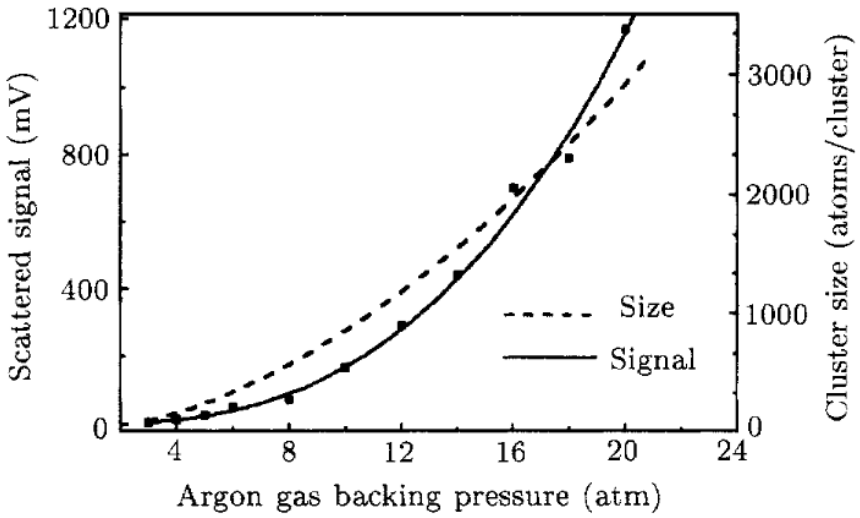
[PNB Neves et al. 10.1063/1.3497651]

$\Omega^{(1,1)}$ [10^{16} cm^2] tabulated for noble gases

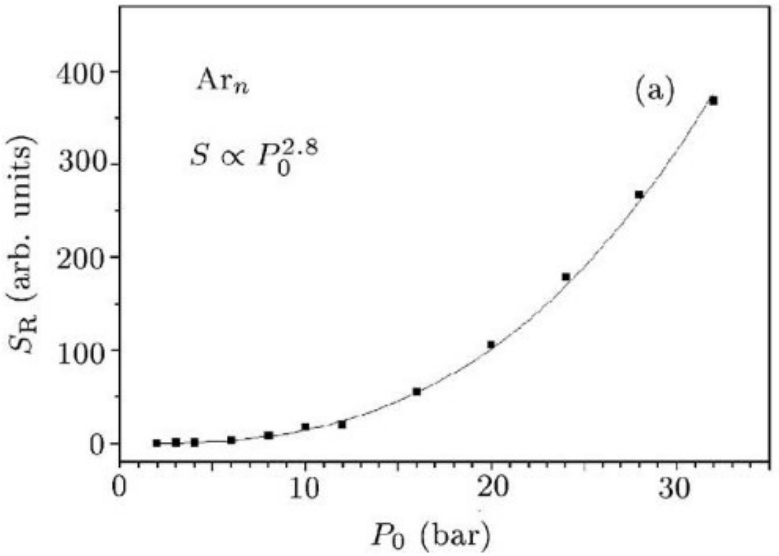
	He	Ne	Ar	Kr	Xe
He^+	73.4				
Ne^+	28.8/30.2*	82.5	88.7 *		
Ar^+	27.1	only 77 K	157		
Kr^+	29.4/29.0*		~94 +	~190 +	
Xe^+	32.9 *	44.6	93.2 *		~245 +

At $T = T_{\text{eff}}$ = 300 K except when marked * (294 K) or + (extrapolated).

Literature



[Lei An-Le *et al* 2000 *Chinese Phys. Lett.* **17** 661]



[Liu Bing-Chen et al 2002 Chinese Phys. Lett. 19 659]

Calculation

$$R_c = N_C^{1/3} \cdot r \qquad \frac{d\sigma}{d\Omega} \propto R_C^6$$

$$S_{RS} \propto n_C \frac{d\sigma}{d\Omega} \propto n_C R_C^6 \propto n_C N_C^2$$

$$n_C \approx \frac{n_0}{N_C}$$

$$S_{RS} \propto n_0 N_C \propto P_0 N_C$$

Conclusion

- We measure that 2-3 atom/cluster at 1 Atm and room temp.

- Data analysis and cluster ion map should finish to see the big picture

- Measurement at higher pressures

Thank You !