Methods of Continuous Scanning in Cluster and Nanoparticle Mobility Analysis

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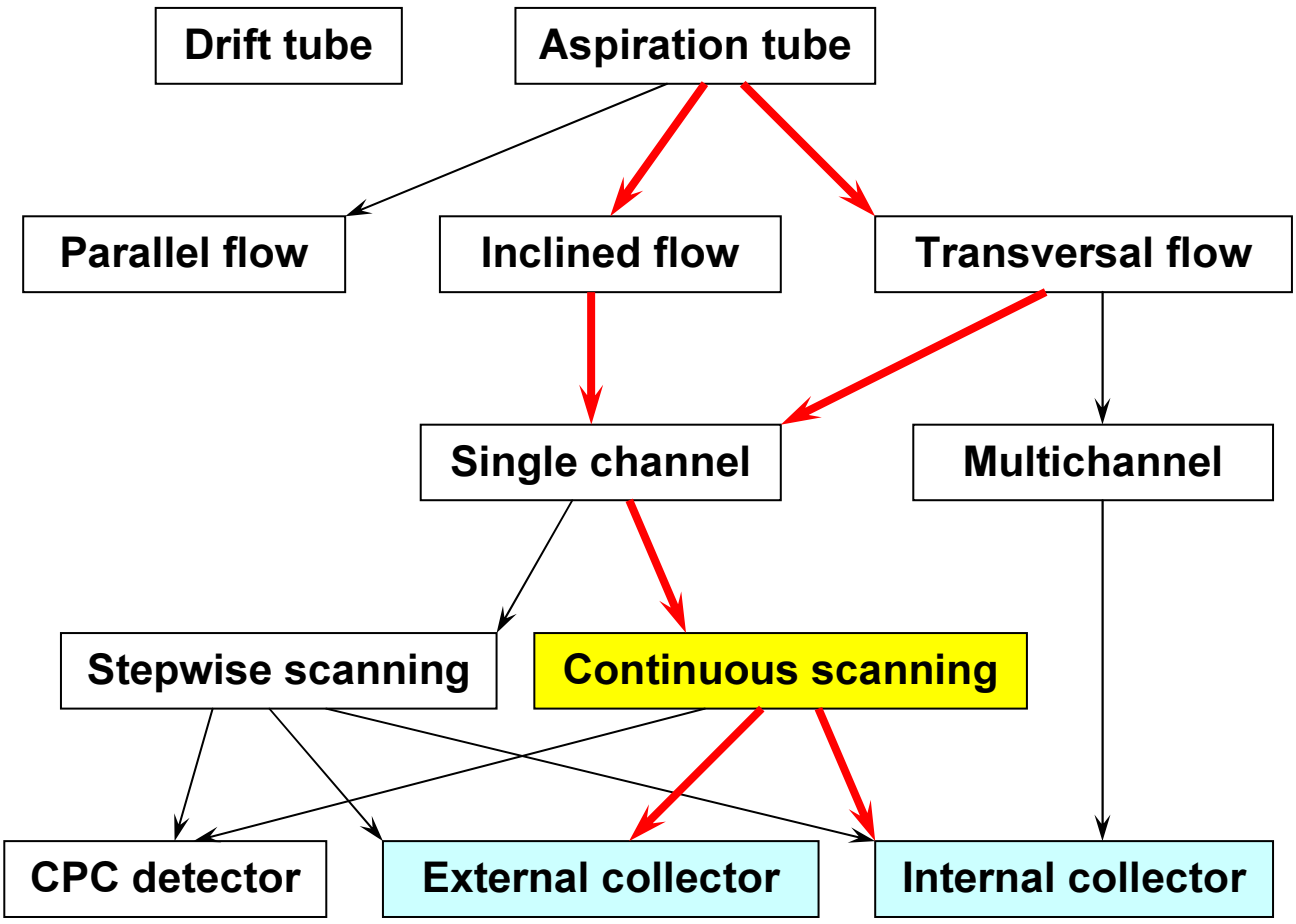
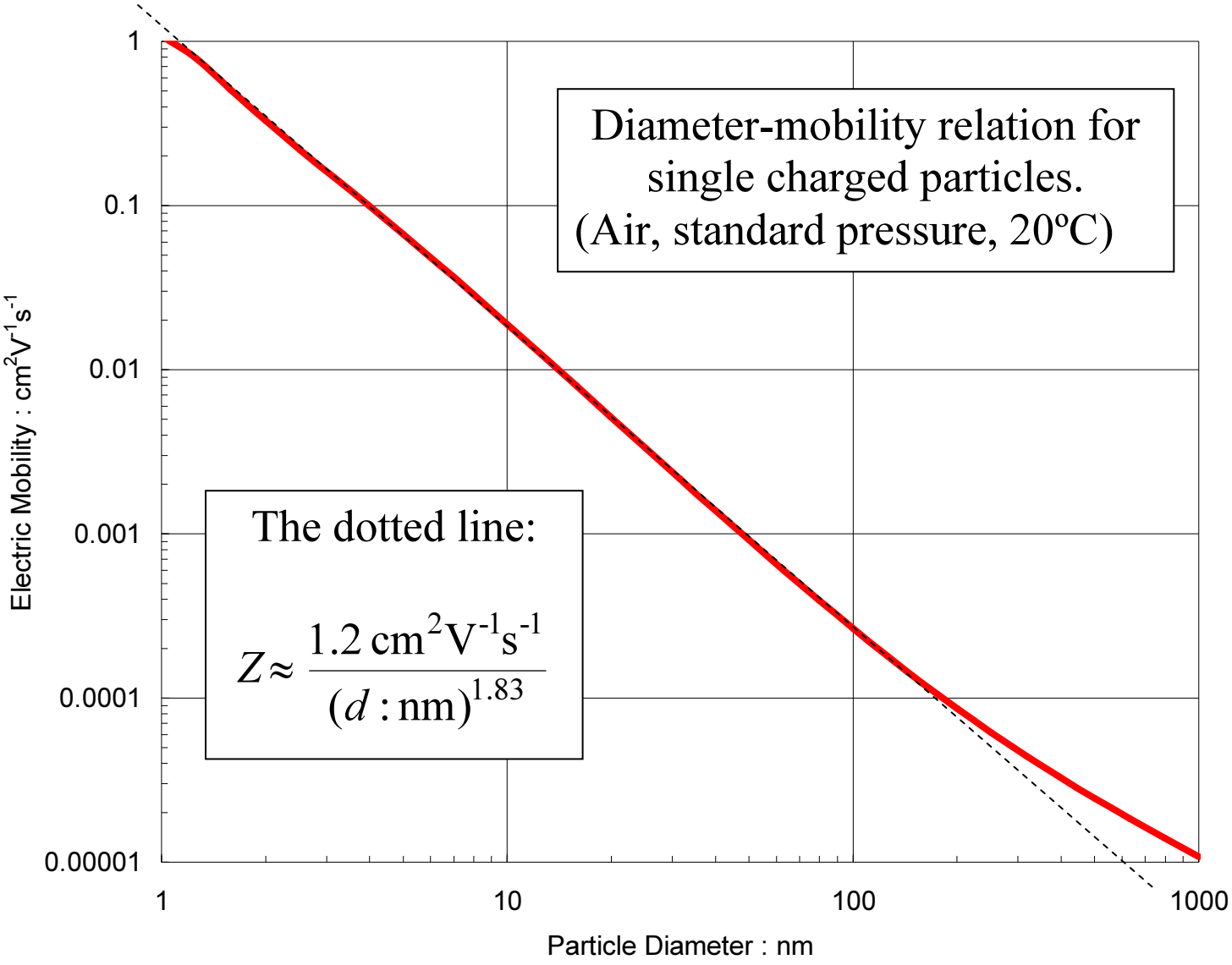
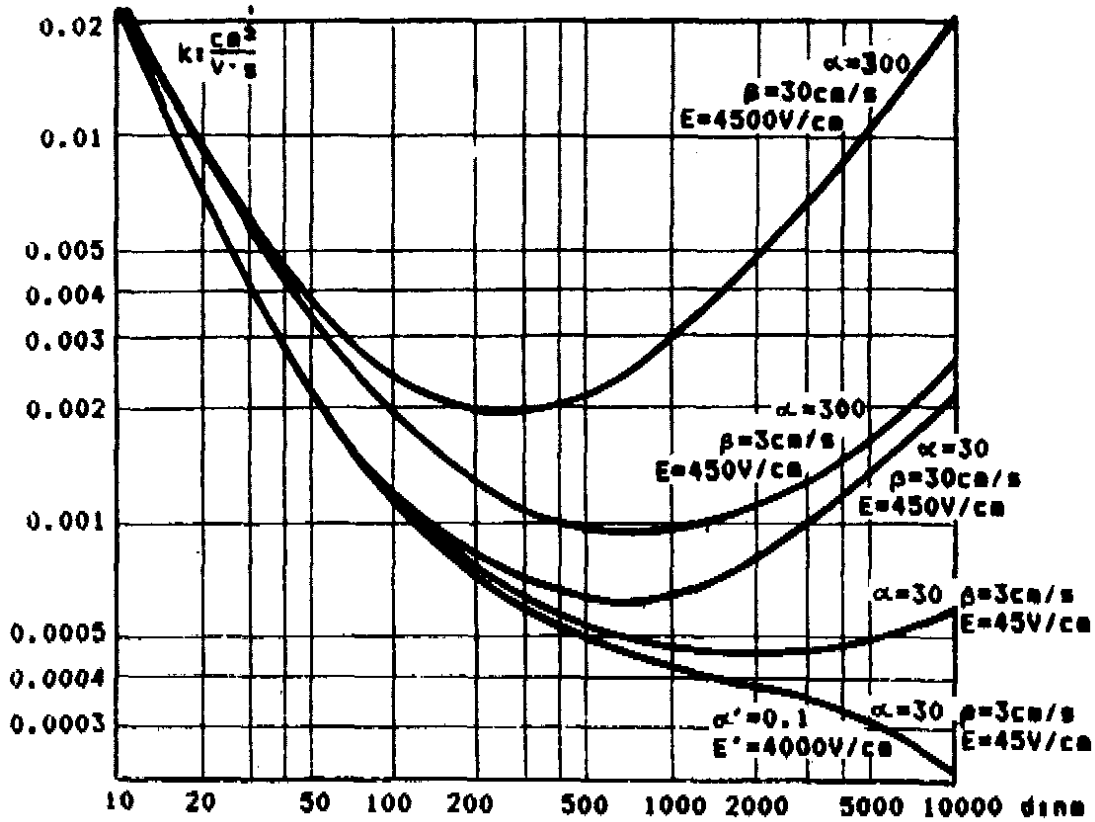
Classification of methods of mobility analysis according to:

- air flow: drift tube, parallel flow, transversal flow, inclined flow;
- recording of distribution: single channel stepwise scanning, single channel continuous scanning, multichannel measurement;
- particle detection: CPC detector, external collector electrometer, internal collector electrometer,

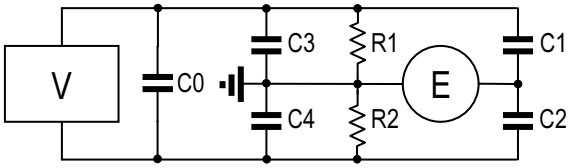



Diameter-mobility relation for single charged particles. (Air, standard pressure, 20ºC)
The dotted line:
$Z \approx \frac{1.2\,\mathrm{cm^2V^{-1}s^{-1}}}{(d:\mathrm{nm})^{1.83}}$
Electric Mobility : $cm^2V^{-1}s^{-1}$
1
0.1
0.01
0.001
0.0001
0.00001
1
10
100
1000
Particle Diameter : nm

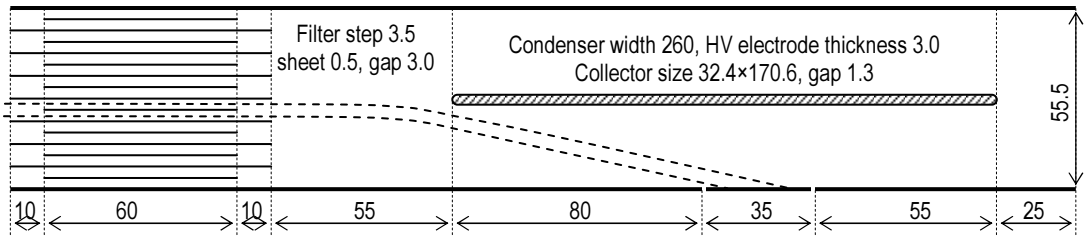

0.02
0.01
0.005
0.004
0.003
0.002
0.001
0.0005
0.0004
0.0003
α=300
β=30cm/s
E=4500V/cm
α=300
β=3cm/s
E=450V/cm
α=30
β=30cm/s
E=450V/cm
α=30
β=3cm/s
E=45V/cm
α'=0.1
E'=4000V/cm
α=30
β=3cm/s
E=45V/cm
10
20
50
100
200
500
1000
2000
5000
10000
dina

Balanced Scanning Mobility Analyzer

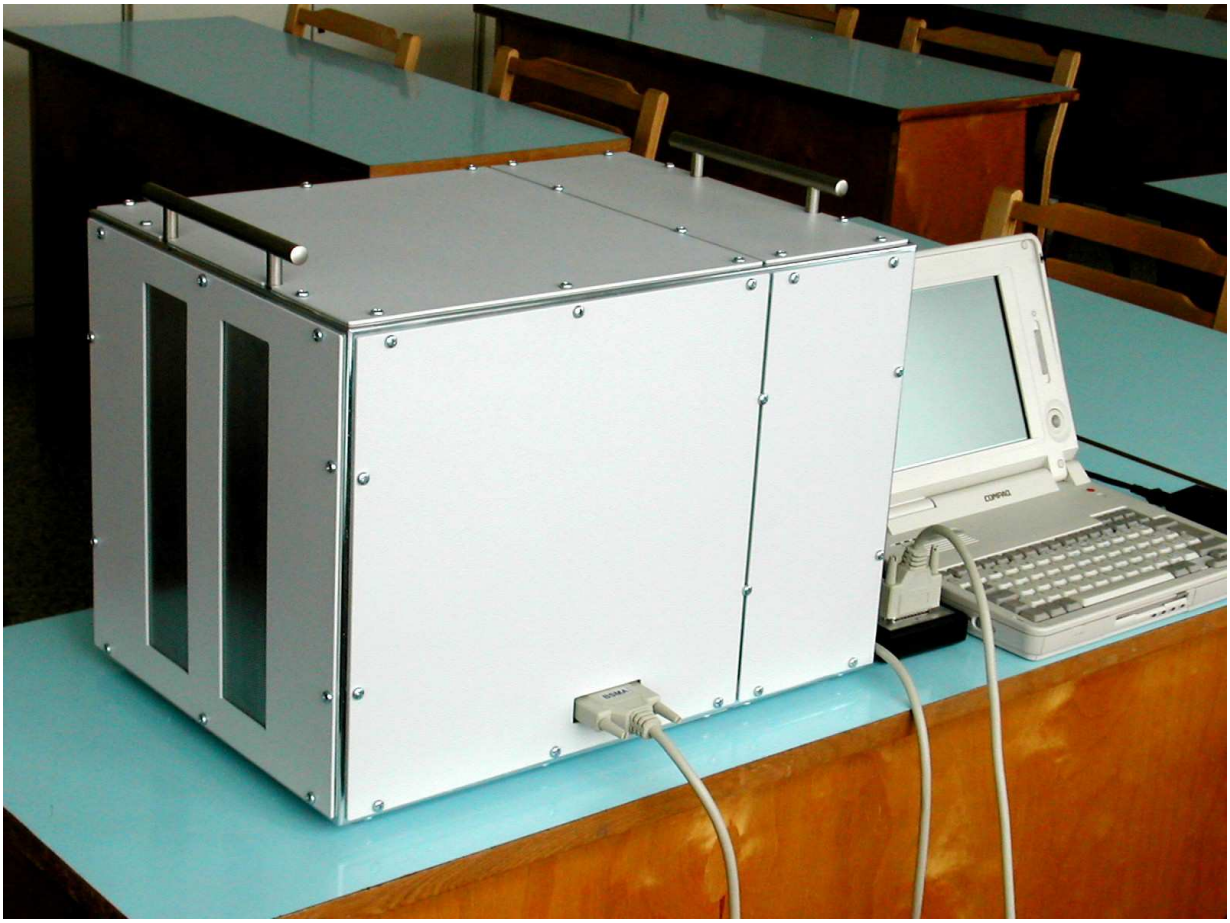
BSMA

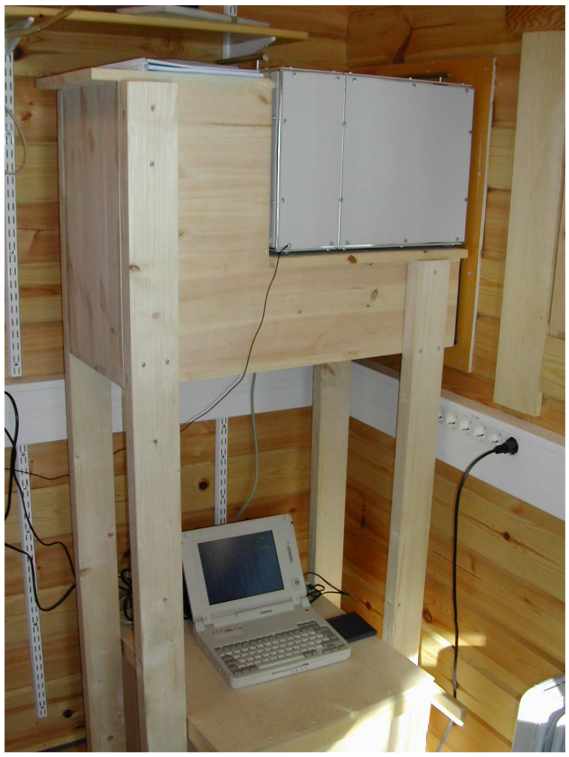


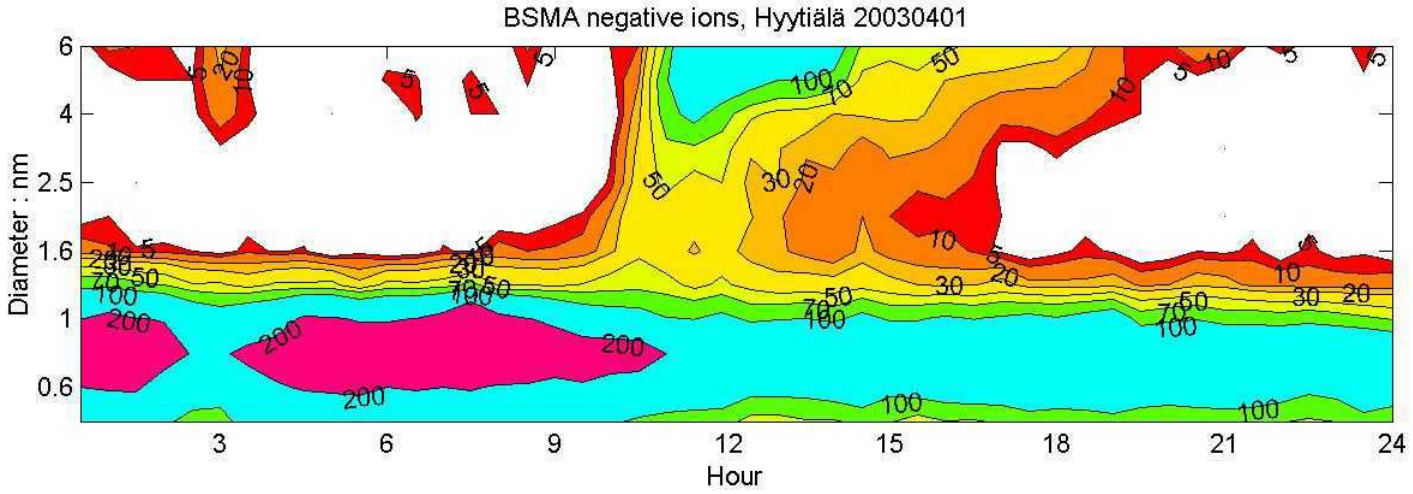
The bridge circuit



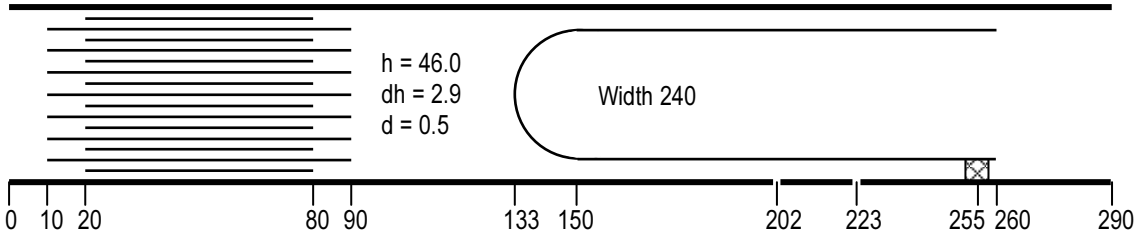
Section of an aspiration condenser in BSMA

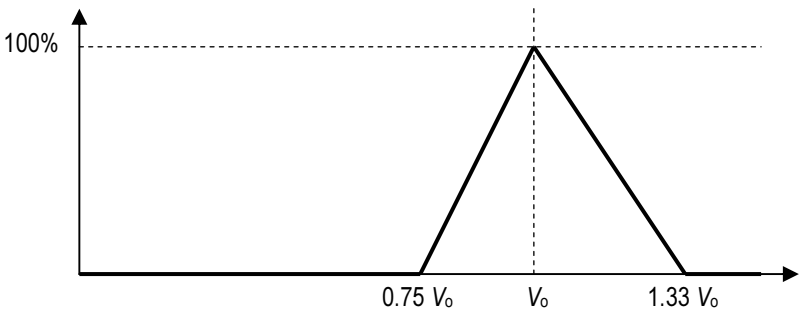





BSMA negative ions, Hyytiälä 20030401
Diameter : nm
6
4
2.5
1.6
1
0.6
3
6
9
12
15
18
21
24
Hour

BSMA2


h = 46.0
dh = 2.9
d = 0.5
Width 240
0
10
20
80
90
133
150
202
223
255
260
290


100%
0.75 V_o
V_o
1.33 V_o

Turbo Pascal 7.0

BSMA2D version HT20040402 scanning mobility distribution

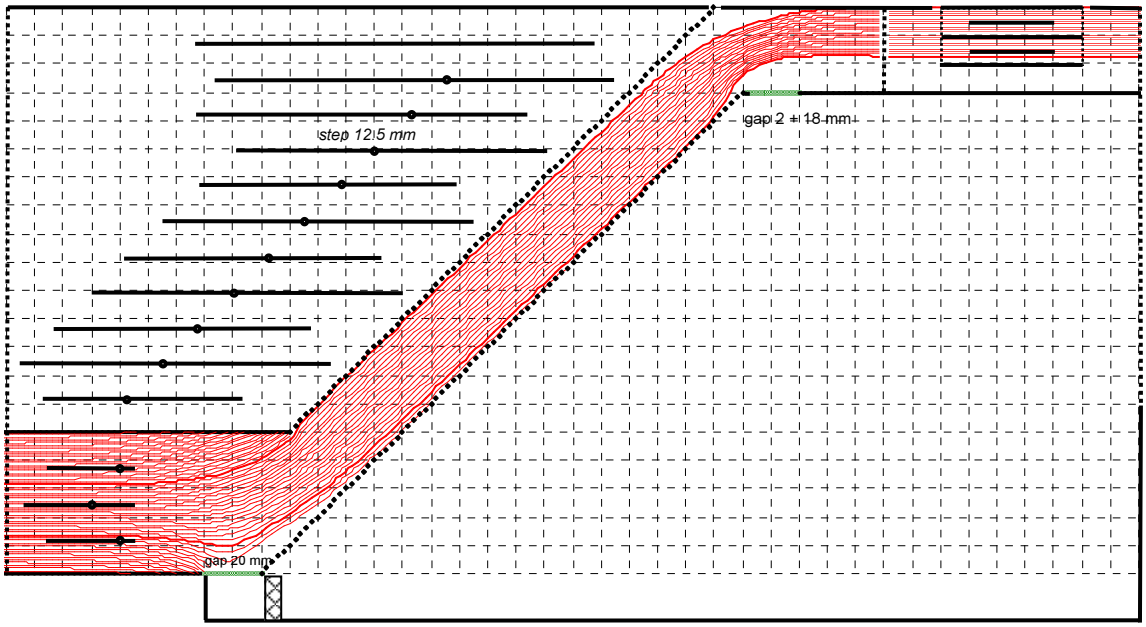
Parameter	Values of parameters ...									
Time HH:MM	23:59		00:00		00:01		00:02		00:03	
T : C	21.4		21.4		21.4		21.4		21.4	
RH : %	50.2		50.2		50.2		50.2		50.2	
p : mb	1021.6		1021.6		1021.6		1021.6		1021.6	
+- noise -+	+ 2	-	+ 2	-	+ 2	-	+ 3	-	+ 2	-
Mobility↓	Mobility fraction concentrations cm-3 ...									
0.018-0.024	45	91	54	95	51	92	47	99	55	89
0.024-0.032	43	81	43	85	40	85	41	83	51	78
0.032-0.042	39	62	43	73	40	75	45	68	45	72
0.042-0.056	38	63	38	61	32	58	36	61	36	59
0.056-0.075	32	53	28	51	30	48	31	51	30	52
0.075-0.100	22	46	24	44	23	44	21	46	23	44
0.100-0.133	18	45	21	43	27	34	21	38	20	39
0.133-0.178	16	30	16	26	13	33	18	22	12	28
0.178-0.237	10	25	10	20	14	17	12	22	6	23
0.237-0.316	8	6	5	6	6	9	4	10	2	9
0.316-0.422	-0	5	1	4	1	3	-1	2	-3	10
0.422-0.562	0	9	1	4	3	6	-1	6	3	0
0.562-0.750	65	12	68	11	68	12	70	10	69	8
0.750-1.000	117	17	122	16	122	20	123	21	123	20
1.000-1.334	200	98	198	103	202	96	200	101	198	98
1.334-1.778	119	203	120	205	117	192	123	203	123	196
1.778-2.371	27	151	31	149	31	152	32	150	28	153
2.371-3.162	-3	45	2	47	5	50	-2	49	-2	52
Diameter↓	Size fraction concentrations cm-3 ...									
0.40-0.63	22	185	31	185	34	191	28	189	24	194
0.63-1.00	273	289	274	294	274	277	278	291	277	282
1.00-1.58	230	56	237	53	239	57	240	57	240	51
1.58-2.51	11	24	9	18	13	21	6	22	2	26
2.51-3.98	41	93	46	84	50	80	48	76	37	84
3.98-6.31	86	152	85	147	80	141	82	149	84	147
6.31-10.0	123	225	135	243	125	242	129	239	145	230
n-cluster	525	526	541	531	546	522	546	535	540	528
Z-cluster	1.15	1.67	1.17	1.68	1.18	1.69	1.16	1.68	1.15	1.70
d-particle	6.0	5.8	6.0	6.0	5.9	6.0	6.0	6.0	6.3	5.9

Scan 16+ -28 -21 -17 -20 -18 -18 -19 -20 -19
00:04:31 -21 -22 -21 -7 5 20_

Balance: manual 54%, automatic 67%; Power 23.7 V; Electrometer bias -0.2 mV
Diurnal files on (Ctrl+M turns off) EXIT = Ctrl+X

Inclined Grid Mobility Analyzer

IGMA



Passage of ions of central mobility in an ideal modified IGMA.

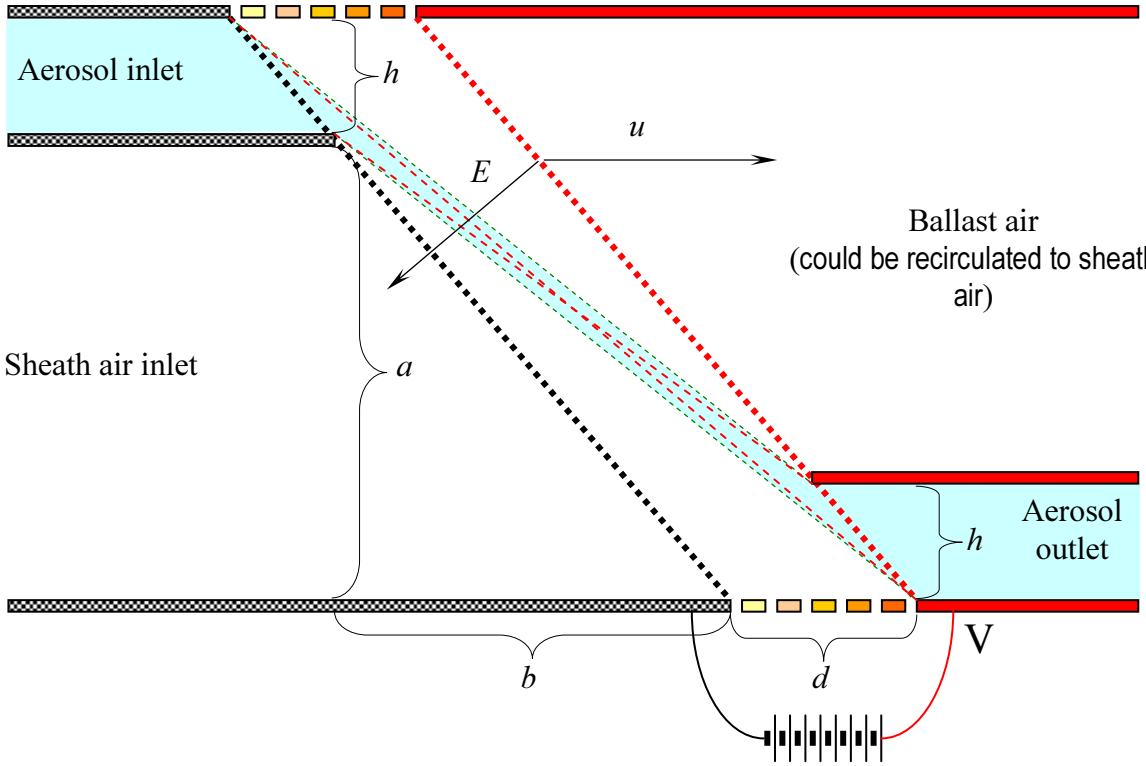
The mobility range of 0.05–3.2 $cm^2\ V^{-1}\ s^{-1}$ is logarithmically distributed into 18 fractions. The flow rate in the inlet slit is 0.05 m^3/s. The air ion inlet is equipped with a controlled electrostatic filter that is used as a gate to close or open the ion entrance into the instrument. During the 3 minute recording period the mobility distribution is 9 times scanned through the full range, five times with open inlet gate and four times with closed inlet gate.

The sheath air should be free of ions. A stack of plate electrodes is used as an internal electrostatic filter just before the grid. The ballast air is recirculated to the sheath air and passed on its way through a long electrostatic filter.

The ions in the outlet are collected by a well-insulated and shielded electrostatic filter powered by an internal battery and DC-DC converter. The collector is connected to the ground through an electrometric amplifier. Electrostatic shielding from the high voltage deflector grid allows free manipulation with mobility control voltage. The deflector grid is connected to a RC circuit with a time constant of about 4 s. The capacitor of this circuit is quickly charged up to 6 kV and slowly discharged through the resistor with a period of 20 s. This assures the logarithmical scanning of mobility from the lowest to the highest value of the mobility range during the 20 s period.

Inclined Grid Mobility Analyzer

IGMA



ADVANTAGES AND DISADVANTAGES OF A PLAIN IGMA

Advantages:

- high mobility resolution,
- easy to keep plug air flow in the instrument,
- simple theoretical calculations,
- calculated transfer function could be trusted without comparative calibration.

Disadvantages:

- one of the aerosol inlet or outlet is on high electric potential,
- loss on charged particles on attracting grid,
- driving voltage is not effectively used because the beam of monomobile particles does not fill the space between grids.

Old papers in *Acta et comm. Univ. Tartu*:

Multichannel method and particle charging:

Tammet, H.F., Jakobson, A.F. and Salm, J.J. (1973) Multi-channel automatic air ion spectrometer (in Russian). *Acta Comm. Univ. Tartu* **320**, 48–75.

Tammet, H.F. (1980) On the techniques of electrical granulometry of aerosols (in Russian). *Acta Comm. Univ. Tartu* **534**, 55–79.

English translation:

Tammet, H. (1992) On the techniques of aerosol electrical granulometry. *Acta Comm. Univ. Tartu* **947**, 94–115.
Available in Web: http://ael.physic.ut.ee/kf.public/sci/publs/acta/947/L.PDF

Continuous scanning:

Tammet, H.F., Hilpus, A.O., Salm, J.J. and Üts, E.J. (1977) An air ion spectrometer for the detection of some admicture in air (in Russian). *Acta Comm. Univ. Tartu* **409**, 84–88.

Tammet, H (2003). Method of inclined velocities in the air ion mobility analysis. *Proceedings of the 12th International Conference on Atmospheric Electricity* **1**, Versailles, pp. 399-402.

From: Leonidas Ntziachristos, Barouch Giechaskiel, Jyrki Ristimäki, and Jorma Keskinen (2004) Use of a corona charger for the characterisation of automotive exhaust aerosol. *J. Aerosol Sci*., in press.