BSMA2
&
some examples of nucleation in urban air

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Advantages of BSMA

- Absolute calibration according to measurements of air flow, electric current and voltage.

Clusters and smallest nanoparticles are subjects of rapid transformations. The size distribution can be rapidly changed when the air is heated during the passage through the inlet tubing and the mobility analyzer.

- Passage time of the air from inlet to collector less than 0.1 s.
- Heating of the air during passage less than 0.3 K.

The multichannel method offers the best size and time resolution in the case of the very low concentration of particles. A specific disadvantage of the multichannel method is that the measurement errors are specific for channels, and it is not easy to prove that a peculiarity in the measured mobility distribution was not caused by a technical trouble in some individual mobility channel.

- Ions of all mobilities are measured from the same collector with the same electrometer.
Disadvantages of BSMA

- Relatively high noise level.

- Failure of measurements during snowfall, drizzling rain and fog.

- Problems in case of high relative humidity.

- Pollution of inlet mesh and filter with small insects during summer measurements.

- Inconvenient procedure of cleaning of insulators.
Objectives for design and manufacturing of BSMA2

- Improvement and test of aspiration condenser.
- Improvement and test of the measurement software.
- Careful calibration of the instrument.
- Nucleation measurements in Tartu.
Aspiration condenser

Filter:
- $h = 46.0$
- $\Delta h = 2.9 = 2.4 + 0.5$

Air flow width 240
Collector size 20×170, gap 1.0

Collector size 20×170, gap 1.5
Electrode 6.0
Clearance 12.0
Standard air flow in one condenser 26 l/s.

Velocity in the filter 2.8 m/s and between electrodes 4.5 m/s.

Reynolds number in the filter about 450 and between the electrodes 3600.

Filter voltage 510 V,
\[ Z = 0.005 \text{ cm}^2\text{V}^{-1}\text{s}^{-1}. \]

Analyzer voltage up to 3000 V,
\[ Z \approx 0.03 \text{ cm}^2\text{V}^{-1}\text{s}^{-1}. \]
Gain control resistor
Electrometer PCB
Sensor connector
High voltage PCB
Control PCB
Specifications
• Length 44 cm, width 32 cm, height 36 cm, mass 16.0 kg.
• Power DC 23-24 V, 60 W or AC 47–63 Hz, 90–260 V, 70 W.
• Suitable power units ZVC65SG24 or Mascot 2020.
• Air flow rate 52 l s⁻¹.
• Passage time of air from the inlet grid to the ion collector 0.06 s.
• Heat emission of the electronics inside of the analyzer section 20 W.
• Increase of air temperature during measurement due to the heat emission 0.2 K.
• Thermal insulation inside of the cover panels: foam polystyrene 10 mm.
• Mobility range 0.032–3.2 cm² V⁻¹ s⁻¹.
• Fraction concentration standard range 0–40000 cm⁻³.
• The range can be increased changing the electrometer gain control resistor.
• Mobility resolution 16 mobility fractions.
• Electrometric amplifier: INA116.
• Humidity of analyzed air in case of unpolluted insulators: up to 99%.
• Standard deviation of a fraction concentration in the conditions of simultaneous measurement of two polarities, 10-minute averaging, clean insulators, moderate radon concentration, moderate humidity, and low wind: about 5 cm⁻³.
Calibration

\[ \gamma = \frac{I}{(ne\Phi_\Delta)} \]

Diffusionless relative transfer function

\[ Z_0 = \frac{h^2 u}{Vl} \]

\[ I(Z_0) = e\Phi_\Delta \int \gamma(Z_0, Z) f(Z) dZ \]

\[ f(Z_0) \approx \frac{24}{7} \frac{I(Z_0)}{e\Phi_\Delta Z_0} \]

\[ n_{(a,b)} \approx 0.99 \frac{I(Z_0)}{e\Phi_\Delta} \]
Measurement program

Mobility scanning scheme: decade to eight fractions.
Span: two decades of mobility.

16 mobility fractions (cm$^2$V$^{-1}$s$^{-1}$):

- $0.032$–$0.042$
- $0.042$–$0.056$
- $0.056$–$0.075$
- $0.075$–$0.100$
- $0.100$–$0.133$
- $0.133$–$0.178$
- $0.178$–$0.237$
- $0.237$–$0.316$
- $0.316$–$0.422$
- $0.422$–$0.562$
- $0.562$–$0.750$
- $0.750$–$1.00$
- $1.00$–$1.33$
- $1.33$–$1.78$
- $1.78$–$2.37$
- $2.37$–$3.16$

Voltage decreases during a 19 second scan exponentially from 3000 V to 25 V.

A 10-minute cycle includes:

- calibration of voltage decay,
- balancing of the bridge circuit,
- about 29 scans of mobility distribution,
- calculation of the size distribution using measurements of air temperature and pressure,
- saving of the results.
<table>
<thead>
<tr>
<th>$d$: nm</th>
<th>$Z$: cm$^2$V$^{-1}$s$^{-1}$</th>
<th>$Z$: cm$^2$V$^{-1}$s$^{-1}$</th>
<th>$Z$: cm$^2$V$^{-1}$s$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>border 10 C &amp; 1050 mb</td>
<td>center 10 C &amp; 1000 mb</td>
<td>40 C &amp; 950 mb</td>
</tr>
<tr>
<td>0.422</td>
<td>2.3646</td>
<td>2.7158</td>
<td>3.0916</td>
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<td>0.487</td>
<td>2.0676</td>
<td>2.3590</td>
<td>2.6706</td>
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<td>1.8005</td>
<td>2.0429</td>
<td>2.3022</td>
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<tr>
<td>0.649</td>
<td>1.5573</td>
<td>1.7593</td>
<td>1.9756</td>
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<tr>
<td>0.750</td>
<td>1.3356</td>
<td>1.5038</td>
<td>1.6840</td>
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<tr>
<td>0.866</td>
<td>1.1347</td>
<td>1.2743</td>
<td>1.4239</td>
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<tr>
<td>1.000</td>
<td>0.9545</td>
<td>1.0697</td>
<td>1.1932</td>
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<tr>
<td>1.155</td>
<td>0.7937</td>
<td>0.8865</td>
<td>0.9847</td>
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<tr>
<td>1.334</td>
<td>0.6432</td>
<td>0.7110</td>
<td>0.7814</td>
</tr>
<tr>
<td>1.540</td>
<td>0.4960</td>
<td>0.5426</td>
<td>0.5920</td>
</tr>
<tr>
<td>1.778</td>
<td>0.3717</td>
<td>0.4071</td>
<td>0.4456</td>
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<td>2.054</td>
<td>0.2816</td>
<td>0.3104</td>
<td>0.3418</td>
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<td>2.371</td>
<td>0.2175</td>
<td>0.2409</td>
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<tr>
<td>2.738</td>
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<td>3.162</td>
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<td>3.652</td>
<td>0.1040</td>
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<tr>
<td>4.217</td>
<td>0.0811</td>
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<tr>
<td>4.870</td>
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<td>5.623</td>
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<tr>
<td>6.494</td>
<td>0.0376</td>
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<tr>
<td>7.499</td>
<td>0.0290</td>
<td>0.0321</td>
<td>0.0354</td>
</tr>
</tbody>
</table>
Mobility distribution is measured alternately in three regimes marked 

\[ + \quad - \quad 0 \]

\( + \) gate of positive ions opened, gate of negative ions closed, 
\( - \) gate of negative ions opened, gate of positive ions closed, 
\( 0 \) both gates closed.

Regimes are alternated as \( 0 - 0 + 0 - 0 + 0 - 0 + 0 - 0 \ldots \)

Scan results are calculated for \( + \) and \( - \) regimes as \( y_i = x_i - (x_{i-1} + x_{i+1}) / 2 \).

Measurement errors are estimated for \( 0 \) regime as \( z_i = x_i - (x_{i-2} + x_{i+2}) / 2 \).

Cycle results are calculated as classified averages of \( y_i \) where minimum and maximum element in a cycle are excluded.

Saved results include for every cycle mobility and size distributions for both polarities, estimate of noise, temperature, pressure, humidity, and some technical control values.
Welcome to BSMA2 control and logging program BSMA2E version HT20041030

Requirements for the computer:
  running under MS DOS or DOS-regime of Windows9#
  free space on disk C for writing of results,
  BSMA2 connected to PICO ADC-16 and the computer LPT1 port,
  ADC-16 connected to the computer COM1 port.
  The program can be interrupted using Ctrl+Break
   (consider Fn key when working with a laptop).

Local winter time:
  Year 2004   Month 11   Day 1
  Hour 20  Minute 10  Sec 43

Selective keys and corresponding tasks are:
  C - Check and adjust the computer clock,
  T - Test operations,
  M - Measure charged particles and clusters,
  N - Noise test (measurement with permanently closed inlet gates),
  X - eXit the program.

Please press a selective key!
(Measurement will automatically start after about 3 idle minutes)
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values of parameters ...</th>
<th>Scanning mobility distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time HH:MM</td>
<td>01:00 01:01 01:02 01:03 01:04</td>
<td></td>
</tr>
<tr>
<td>RH : %</td>
<td>19.9 19.9 19.9 19.9 19.9</td>
<td></td>
</tr>
<tr>
<td>p : mb</td>
<td>1017.6 1017.6 1017.6 1017.6 1017.6</td>
<td>+ 4 - + 8 - + 4 - + 3 - + 5 -</td>
</tr>
<tr>
<td>Mobility↓</td>
<td>Mobility fraction concentrations cm⁻³ ...</td>
<td></td>
</tr>
</tbody>
</table>

| Diameter↓ | Size fraction concentrations cm⁻³ ... |                                |

| N-particle n-cluster | Z-cluster |                                |

| Date | 200505105 |                                |
| Time | 01:05:42 |                                |
| Scan 12 | + ions |                                |
| Power | 24.0 V |                                |
| Filter | +500 / -500 V |                                |
| E-meter bias | -0.1 mV |                                |
| Manual balance | 21 % |                                |
| Autobalance | 67 % |                                |

Data tables on (Alt+D turns off) Plot tables on (Alt+P turns off) Scan details off (Ctrl+S turns on) Exit = Ctrl+X
program PLOTTAB;

......
  writeln ('Data can be smoothed repeating N times',
   ' averaging over the triads of neighbors.');
  writeln ('Recommended standard smoothing grade N = 1.');
  write ('Please tell your choice of the smoothing grade N (0...5) : ');
  readln (grade);

......

function BSMA2PLT; %HT20041106
% Diurnal contour plots from BSMA2E plot tables
% All days of one month in one folder are processed in one session
% Input filenames must be pYYMMDD-xl and nYYMMDD-xl
% Output filenames are [prefix YYMMDD.jpg]
%
% Please modify the input data in following 3 lines:
  prefix = 'BSMA'; % for output file name, could be modified
  filepath = 'C:\PLOT\'; % where the files are located, could be modified
  yymm = '0411'; % year and month, could be modified

......
precipitations

temperature