Study for stochastic cooling at Nuclotron (JINR)

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Introduction

• The idea

*Experiment on stochastic cooling at Nuclotron is a preparatory work for NICA collider*

• 3 years and 3 runs to get longitudinal cooling
Cooling system

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circumference, m</td>
<td>251.5</td>
</tr>
<tr>
<td>Ions</td>
<td>D⁺</td>
</tr>
<tr>
<td>Intensity, particles</td>
<td>10⁹-10¹⁰</td>
</tr>
<tr>
<td>Kinetic energy, GeV/u</td>
<td>3</td>
</tr>
<tr>
<td>Rev. frequency, MHz</td>
<td>1.158</td>
</tr>
<tr>
<td>Flattop time, s</td>
<td>480</td>
</tr>
<tr>
<td>Phase slip factor</td>
<td>0.034</td>
</tr>
<tr>
<td>Initial dp/p</td>
<td>0.55×10⁻³</td>
</tr>
<tr>
<td>Cooling system</td>
<td>Long., notch filter</td>
</tr>
<tr>
<td>Bandwidth, GHz</td>
<td>2-4</td>
</tr>
<tr>
<td>ToF P-K, ns</td>
<td>431.88</td>
</tr>
<tr>
<td>Pick-up impedance, Ohm</td>
<td>144</td>
</tr>
<tr>
<td>Kicker impedance, Ohm</td>
<td>576</td>
</tr>
<tr>
<td>Power for the kicker, W</td>
<td>18</td>
</tr>
</tbody>
</table>
Pick-up and kicker

Ring-slot coupler (pick-up and kicker)

Combiner board

Single ring with 8 electrodes, 9 Ohm in sum mode

“Study for stochastic cooling at Nuclotron, JINR”, N. Shurkhno
Pick-up and kicker

PU combiner boards

Pick-up outputs combination

Pick-up electronics

Kicker electronics

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Optical notch-filter and system delay

- Notch depths > 40dB
- Maximum freq. dispersion ~ 10kHz (~10^6) (maximum deviation of notch position in pass-band)
- Software for automatic adjustment
- Delay line is the part of the optical link (=fibers + fine delay)
Photos

Dismantled notch-filter in the lab

Cooling system rack at Nuclotron

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Open-loop measurements

This was in 2012:

That is now:


“Study for stochastic cooling at Nuclotron, JINR”, N. Shurkhno
Yes, we cool!

Ions: \( D^+ \)

Intensity: \( 2 \times 10^9 \)

Cooling time: 480 s

Initial \( dp/p \): \( 0.55 \times 10^{-3} \)

Final \( dp/p \): \( 0.25 \times 10^{-3} \)
Transverse Schottky-noises

Horizontal Schottky noise:

Vertical Schottky noise:

\[ q_x \approx 0.28 \]

\[ q_y \approx 0.32 \]
Simulations

The cooling process was calculated by solving the Fokker-Planck equation.

Gain behaviour in the passband:

The main amplifier was in saturation during cooling, so \( \text{gain} = ? \text{ dB} \). It can be roughly estimated with known output power of saturated amplifier, system transfer function and distribution function: \( g \sim 114 \text{ dB} \).

Cooling simulation with 110 dB, delay error 20 ps, notch error 10 ps:

Simulation with estimated gain and “ideal” system gives the final momentum spread - 0.1\( \times 10^{-3} \) (2.5 lower than real).

With **110 dB gain**, 20 ps delay error and 10 ps filter delay error simulation repeats the experiment.
Conclusion and outlook

• The 1<sup>st</sup> stage of stochastic cooling experiment at Nuclotron has finished successfully: *during the Nuclotron run in March’13 the momentum cooling of deuteron beam was achieved for the first time and fractional parts of the betatron numbers were measured.*

• For the 2<sup>nd</sup> stage of an experiment it is planned to have C<sup>6+</sup> beam during December run. This should allow us the chromaticity measurements and in principle make possible the Palmer and betatron cooling experiments.