Study for stochastic cooling at Nuclotron (JINR)

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With grateful acknowledgement to
I. Meshkov, H. Stockhorst, L. Thorndall, F. Caspers, V. Lebedev,

COOL'13, 10th -14th June 2013, Mürren, Switzerland

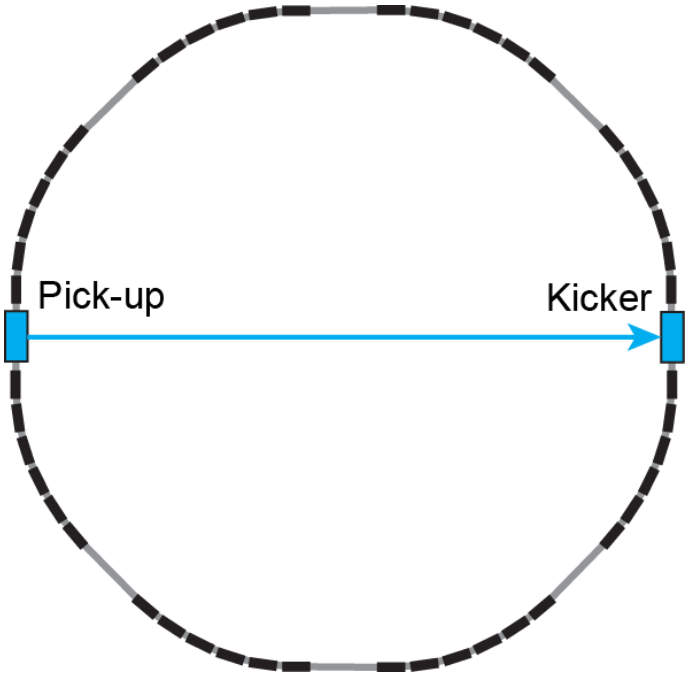
Introduction

- The idea

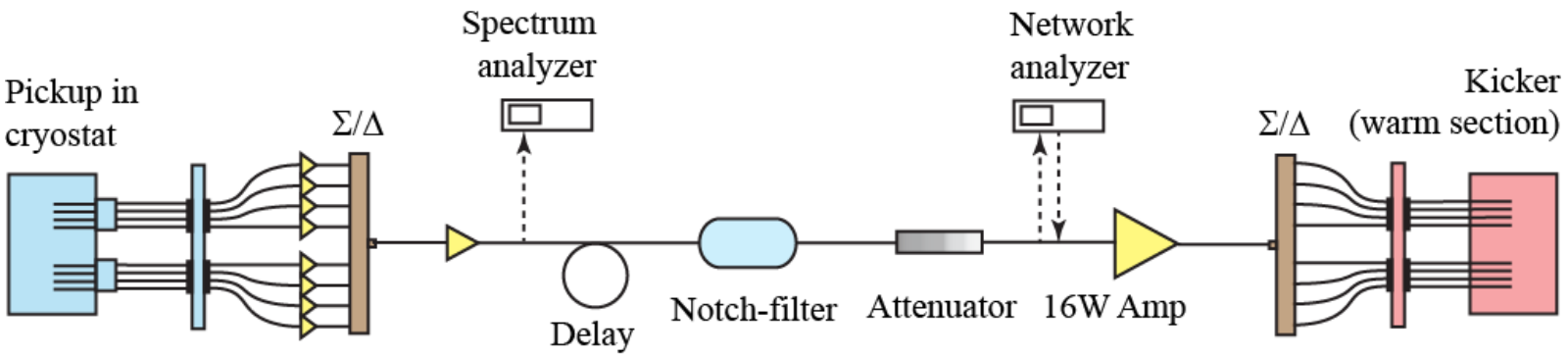
  Experiment on stochastic cooling at Nuclotron is a preparatory work for NICA collider

- 3 years and 3 runs to get longitudinal cooling

Cooling system

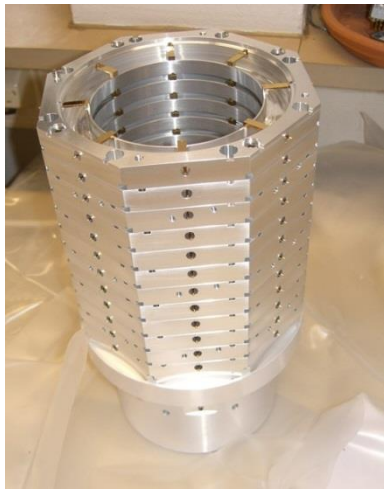


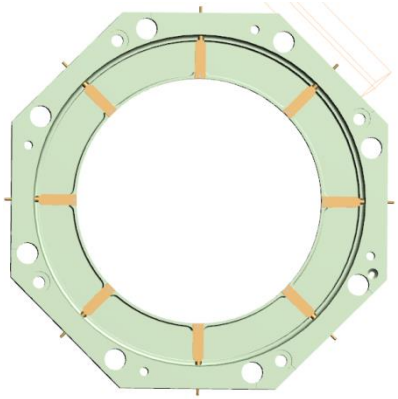
Circumference, m	251.5
Ions	D^+
Intensity, particles	10^9-10^{10}
Kinetic energy, GeV/u	3
Rev. frequency, MHz	1.158
Flattop time, s	480
Phase slip factor	0.034
Initial dp/p	0.55×10^{-3}
Cooling system	Long., notch filter
Bandwidth, GHz	2-4
ToF P-K, ns	431.88
Pick-up impedance, Ohm	144
Kicker impedance, Ohm	576
Power for the kicker, W	18



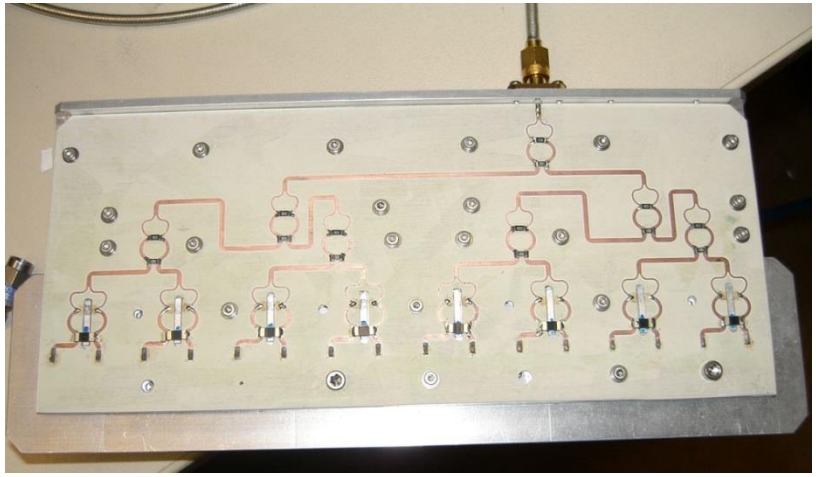
Pick-up and kicker

Ring-slot coupler (pick-up and kicker)



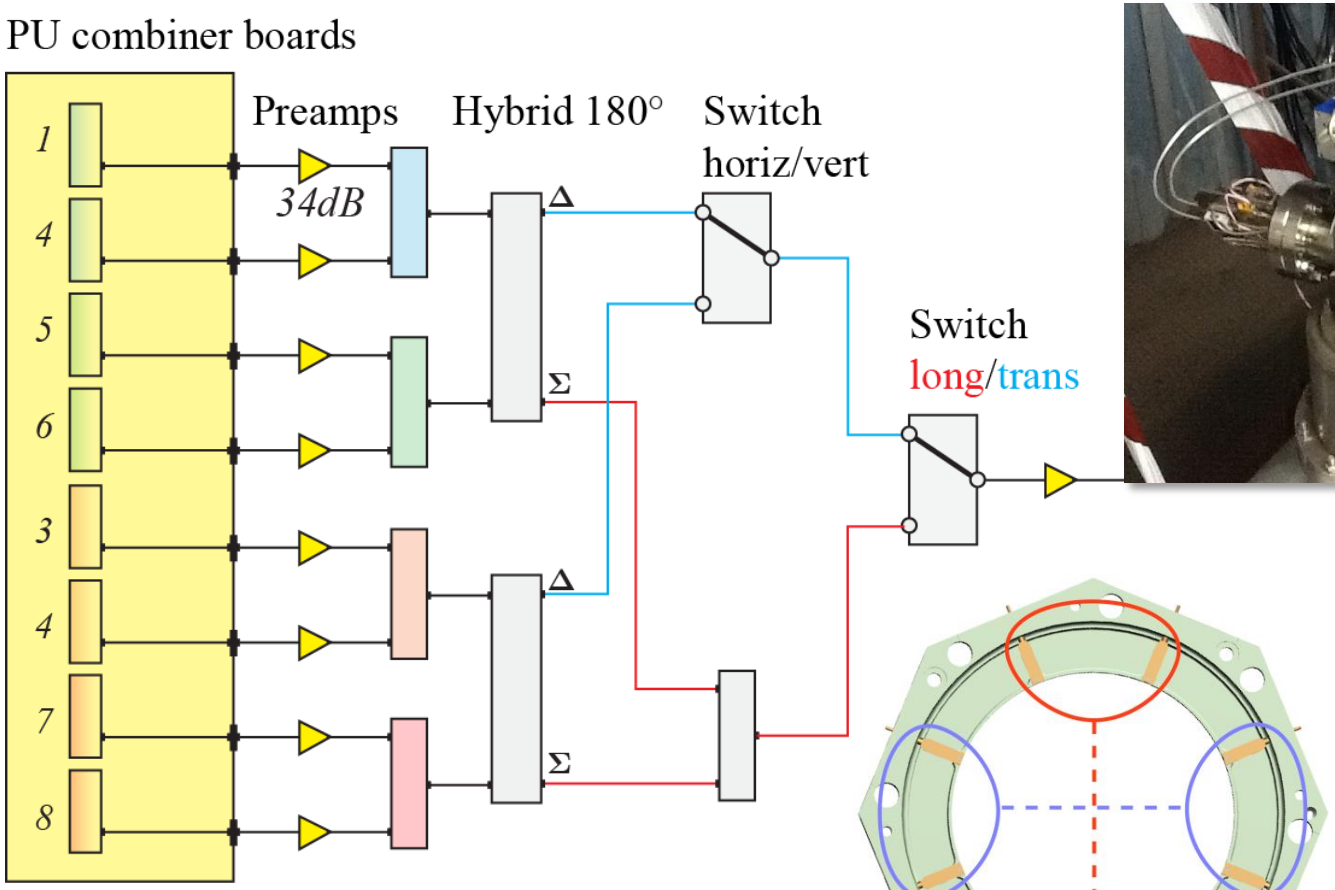


Single ring with 8 electrodes, 9 Ohm in sum mode



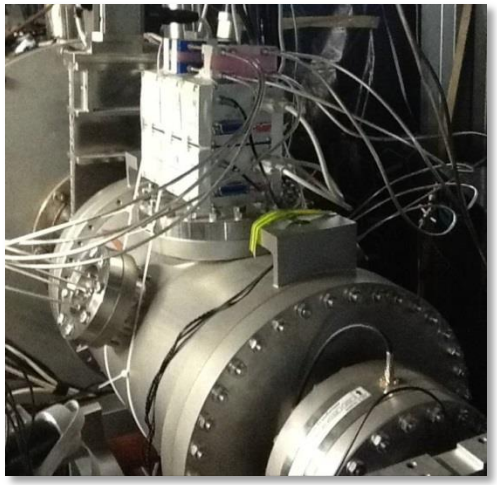
Combiner board

Pick-up and kicker



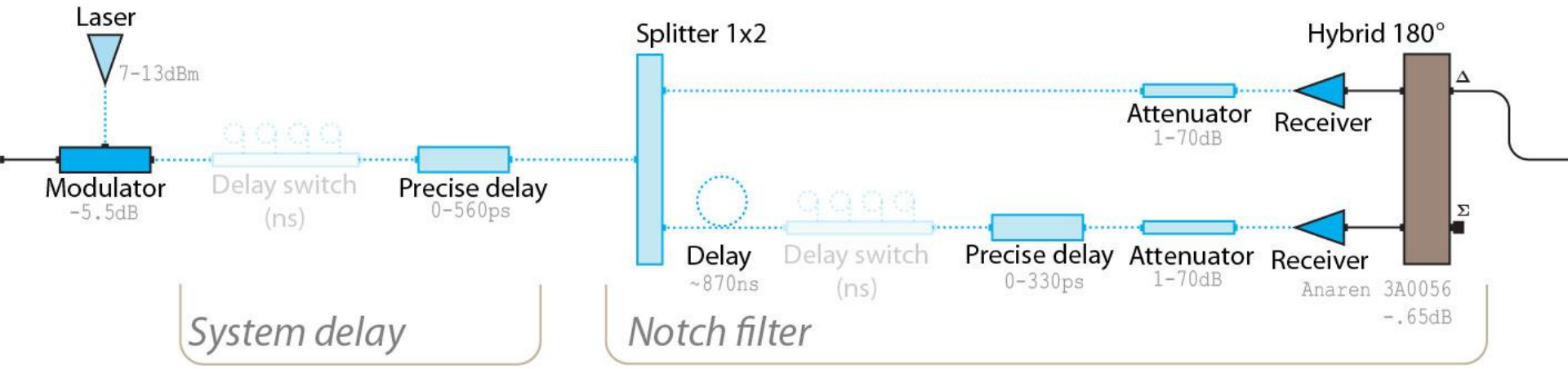
Pick-up outputs combination

Pick-up electronics

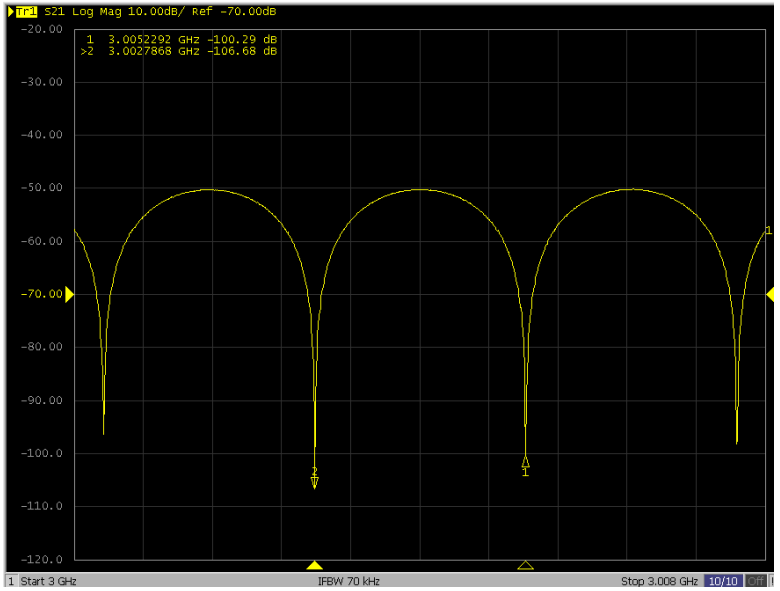


Kicker electronics

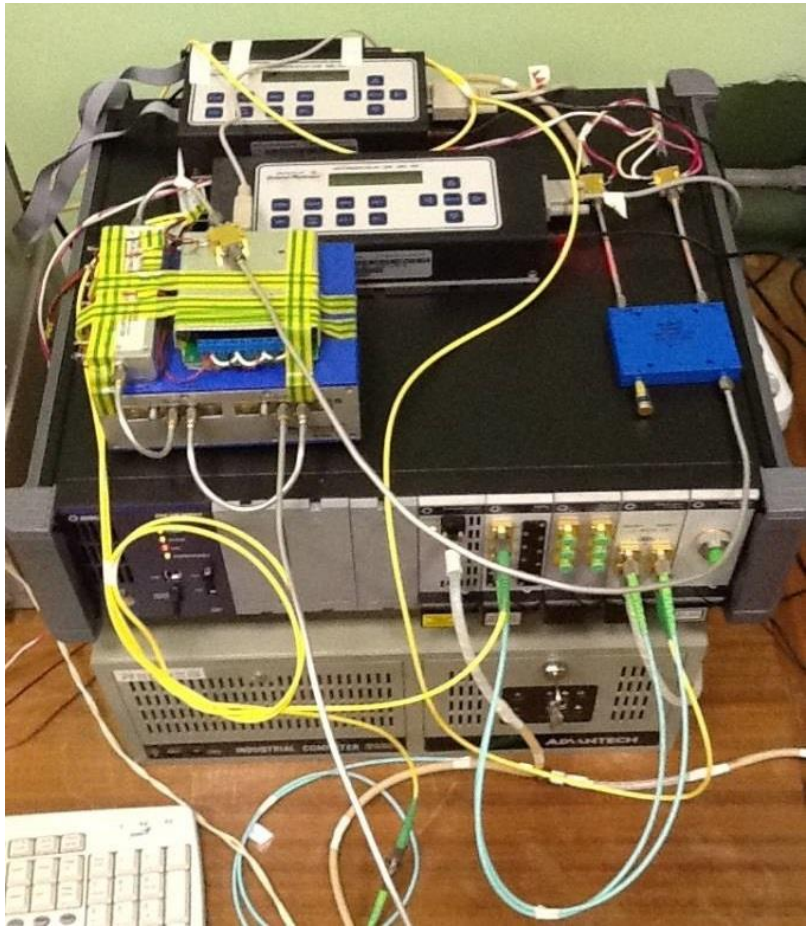
Optical notch-filter and system delay



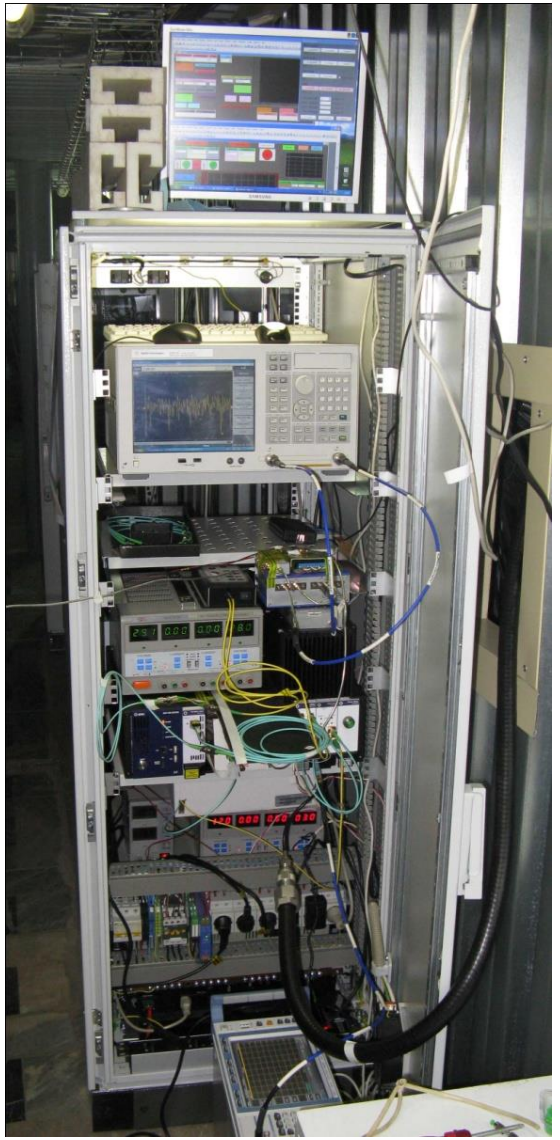
- Notch depths > 40dB
- Maximum freq. dispersion ~ 10kHz (~10^6)
  (maximum deviation of notch position in pass-band)
- Software for automatic adjustment
- Delay line is the part of the optical link
  (=fibers + fine delay)



Photos

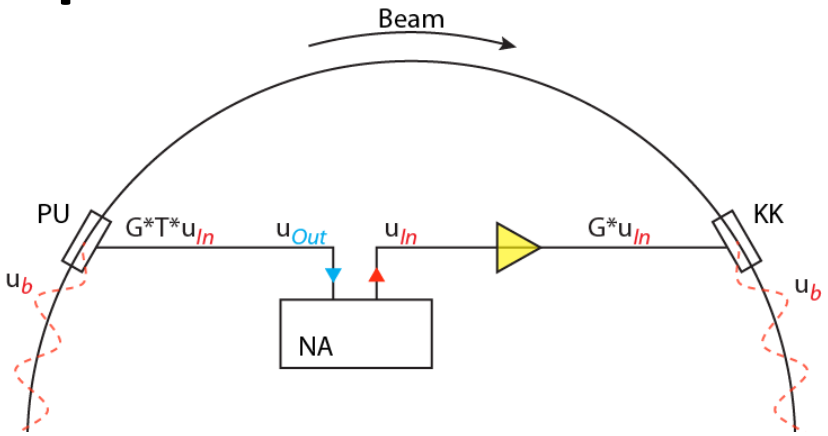


Dismantled notch-filter in the lab

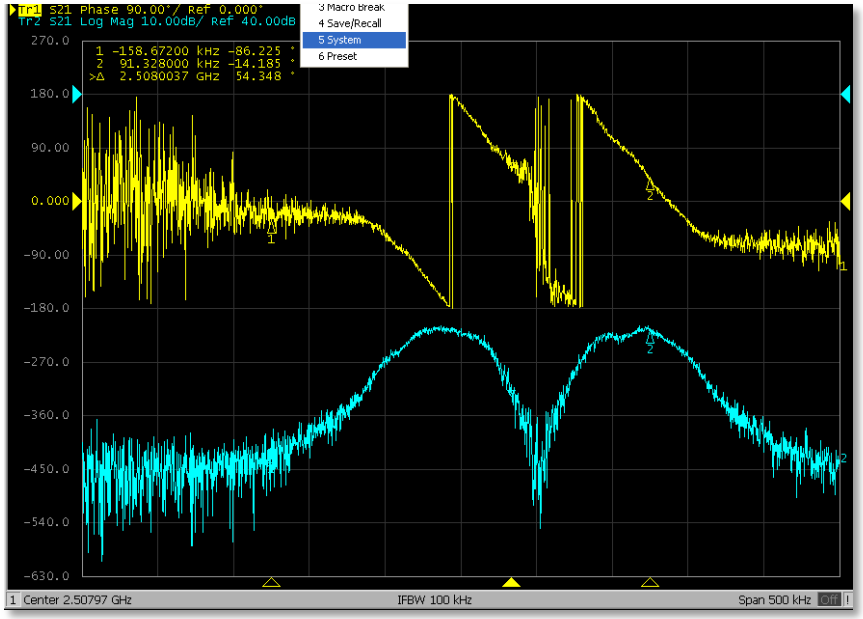


Cooling system rack at Nuclotron

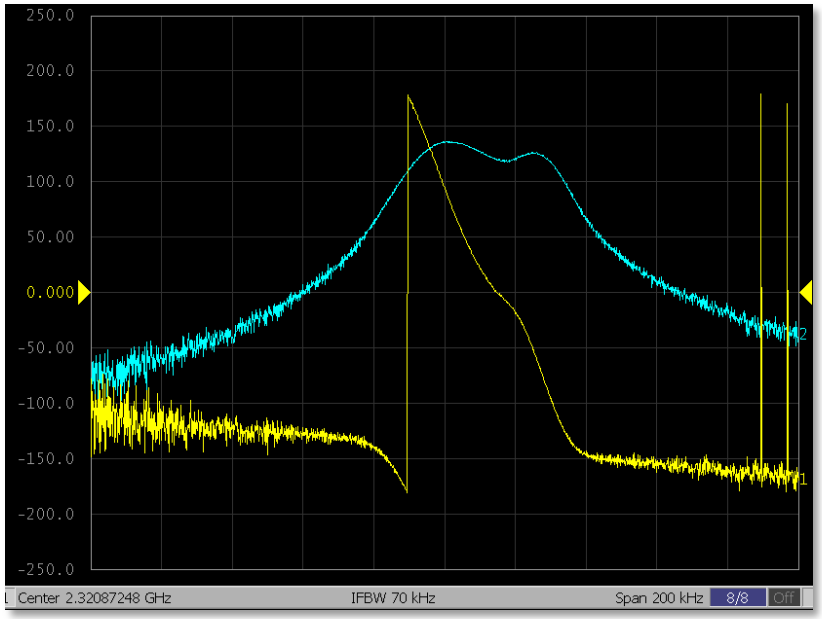
Open-loop measurements



This was in 2012:



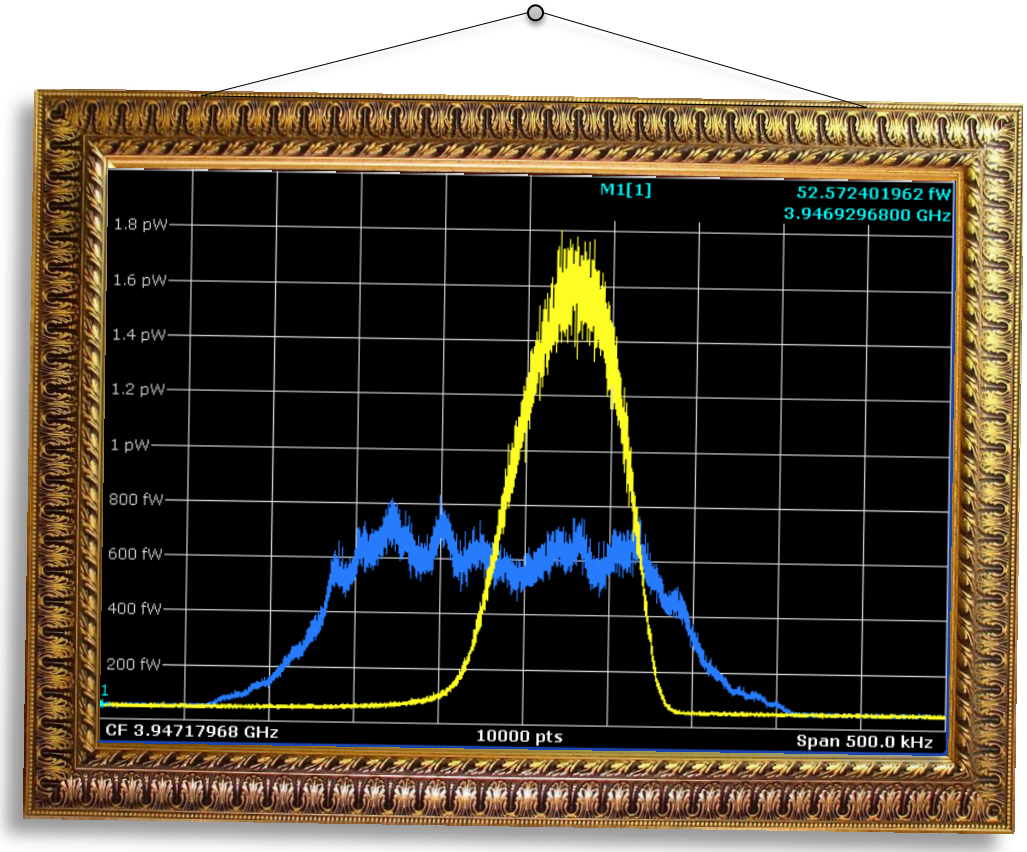
That is now:



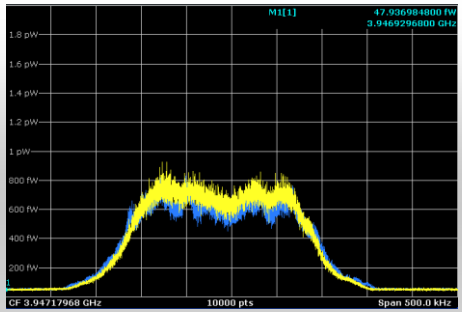
Open-loop measurements. Blue/yellow curves – amplitude/phase responses.

Yes, we cool!

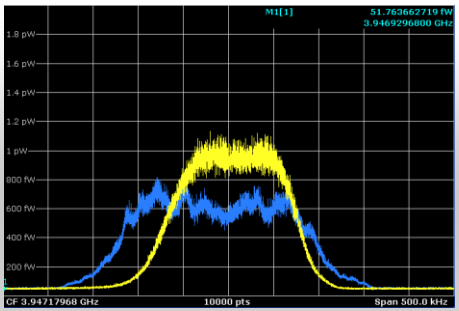
Ions:	D^+
Intensity:	2×10^9
Cooling time:	480 s
Initial dp/p:	0.55×10^{-3}
Final dp/p:	0.25×10^{-3}



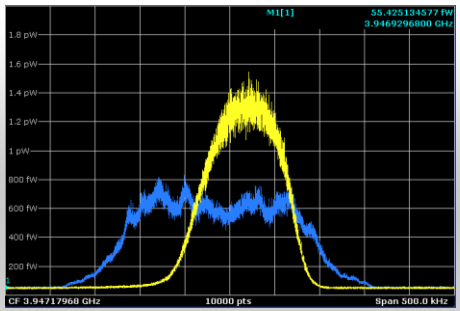
Initial:



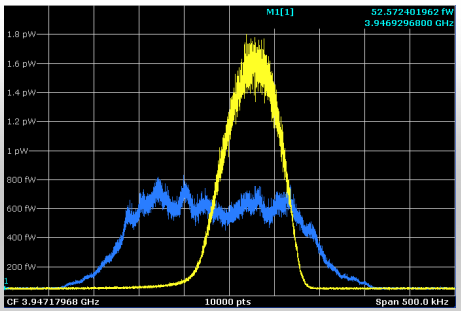
160 s



320 s

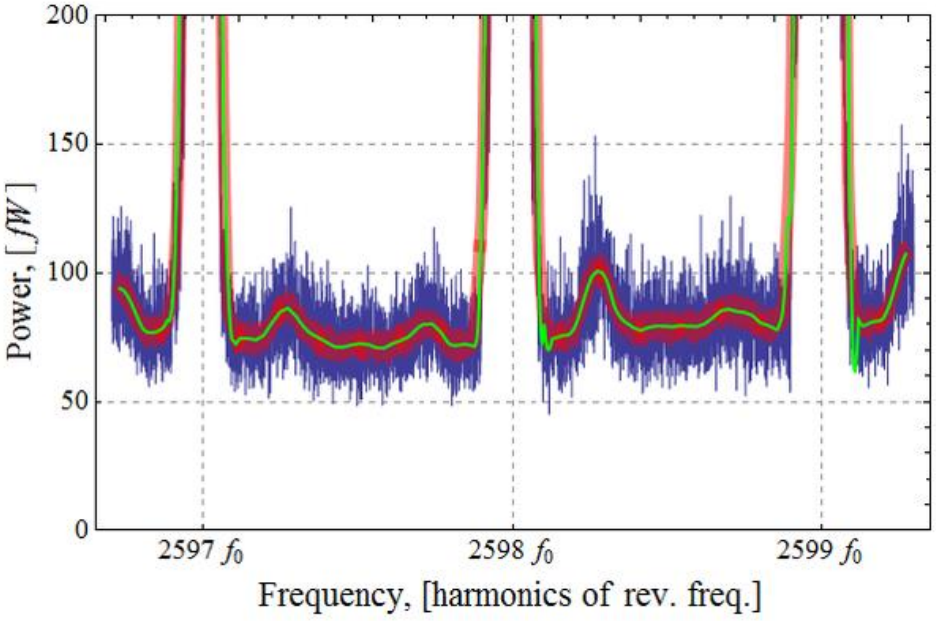


480 s



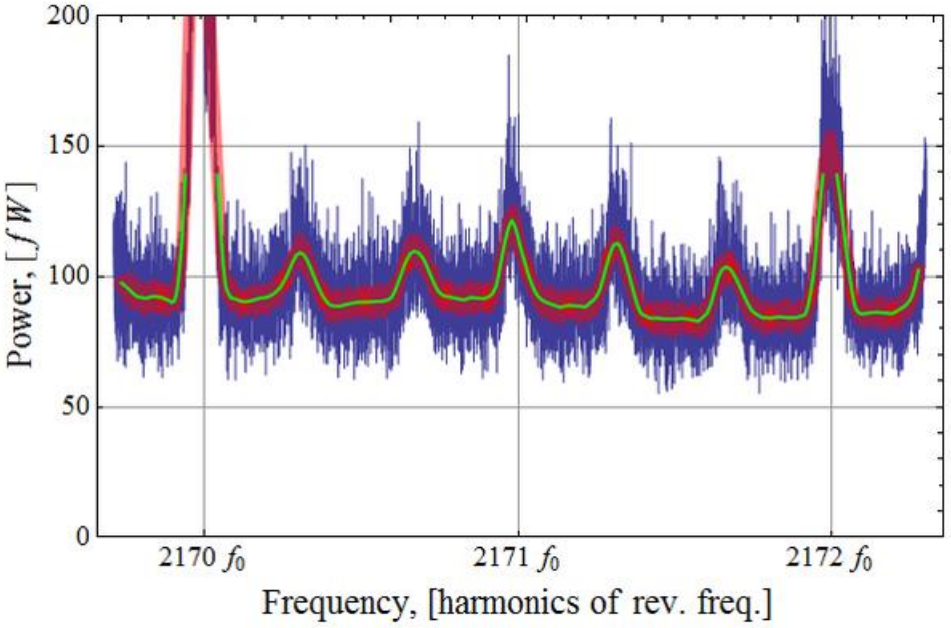
Transverse Schottky-noises

Horizontal Schottky noise:



$$q_x \approx 0.28$$

Vertical Schottky noise:

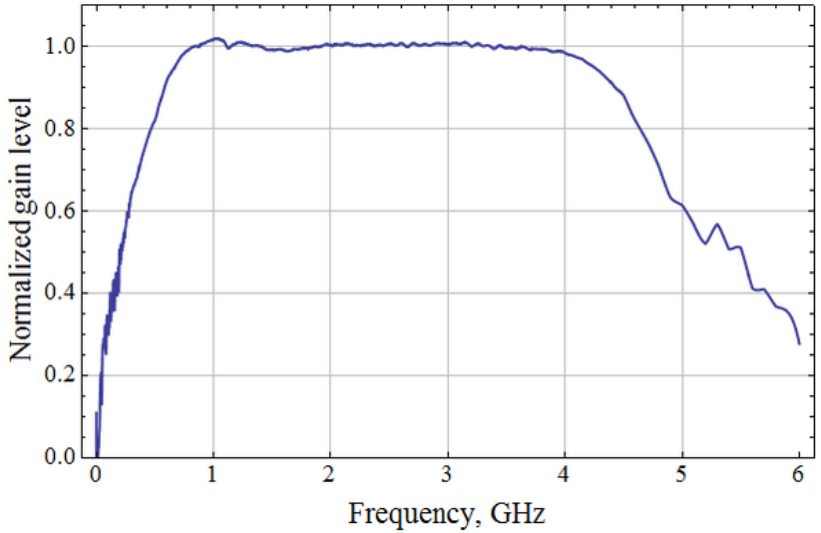


$$q_y \approx 0.32$$

Simulations

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

Gain behaviour in the passband:

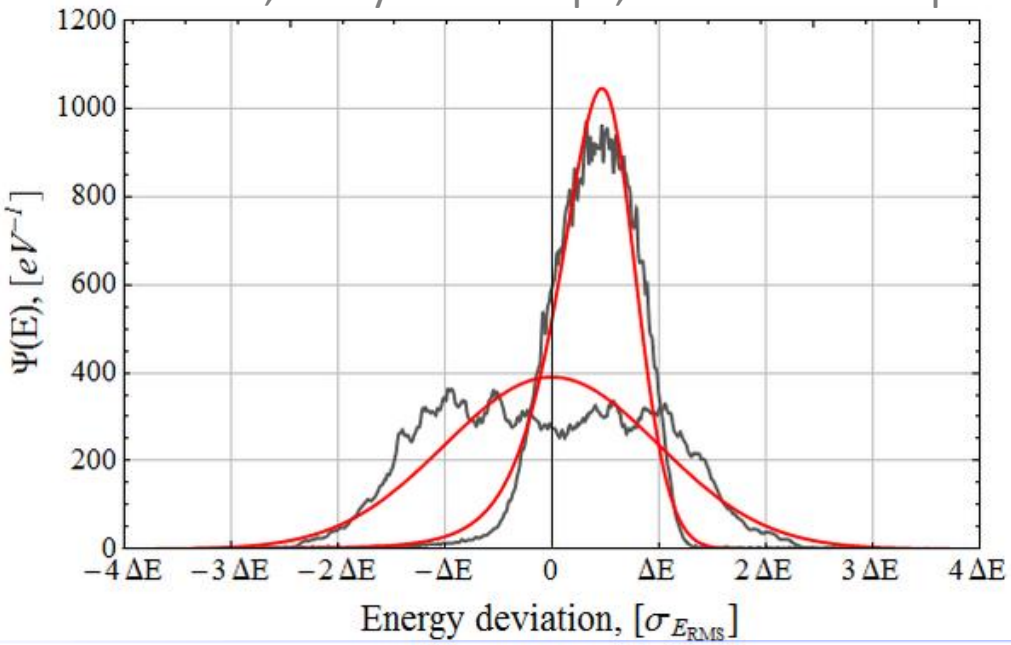


The main amplifier was in saturation during cooling, so gain = ? dB. It can be roughly estimated with known output power of saturated amplifier, system transfer function and distribution function: g ~ 114 dB.

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

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

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



Conclusion and outlook

- The 1st 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 2nd stage of an experiment it is planned to have C^{6+} beam during December run. This should allow us the chromaticity measurements and in principle make possible the Palmer and betatron cooling experiments.