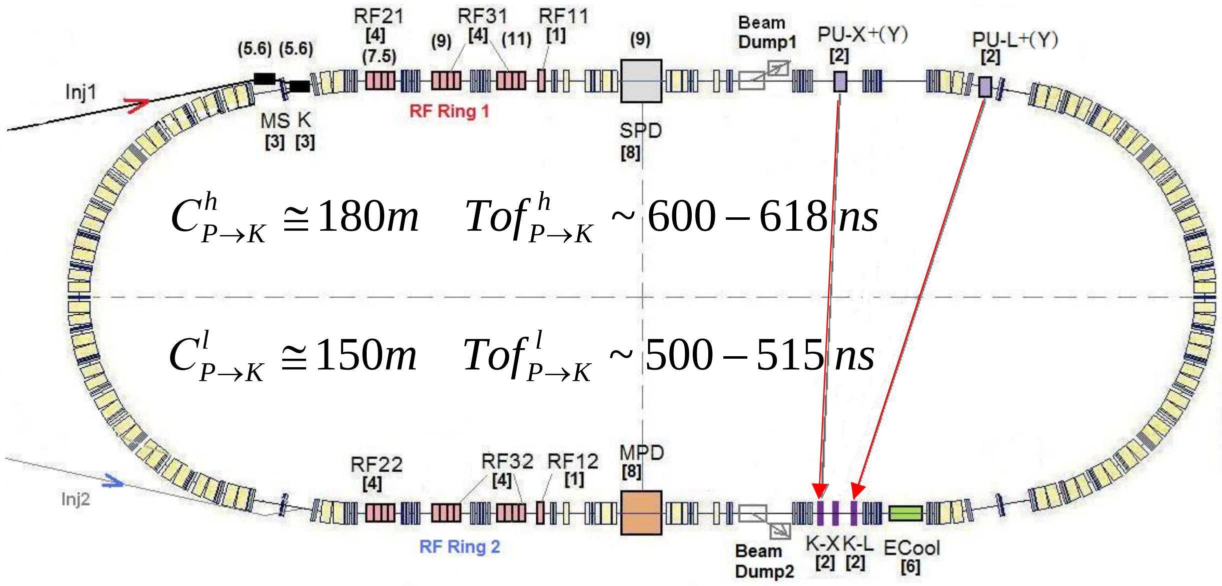
Stochastic cooling for NICA collider

Ivan Gorelyshev, LHEP, JINR

Perspectives for Joint Science and Academic Training at FAIR and NICA

NICA stochastic cooling system

Stochastic cooling is microwave broadband system with feedback via the beam



- High sensitivity pickup at cryogenic temperatures
- Precise processing & delay: range 32ns, 1ps accuracy
- Broadband high power amplifier
- Large impedance kicker dissipates high power

inside chamber at high vacuum

3 channels for each ring: longitudinal + 2 transverse
6 Pickups + 4 Kickers in total

one of the crucial systems of the project

Design on the basis of simulation

Fokker-Planck approach
GSI, FZJ, CERN, FNAL

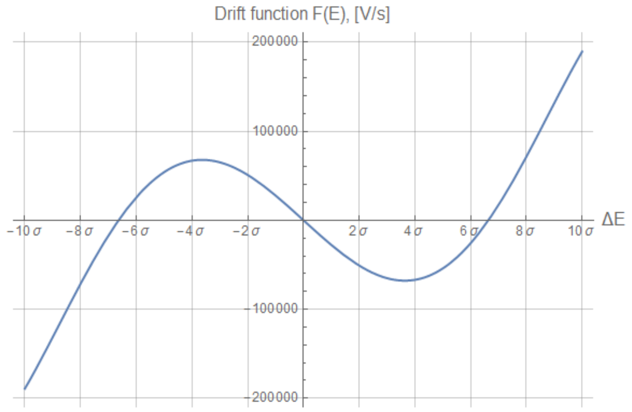
$$\frac{\partial\Psi(E,t)}{\partial t}+\frac{\partial}{\partial E}\left(F(E)\Psi(E,t)-D(E,t)\frac{\partial\Psi(E,t)}{\partial E}\right)=0$$

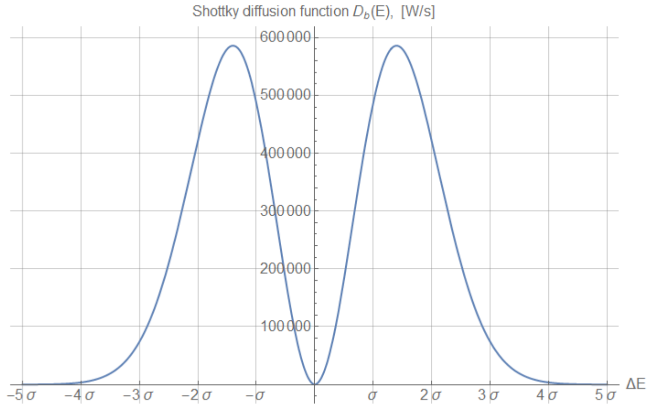
Drift term

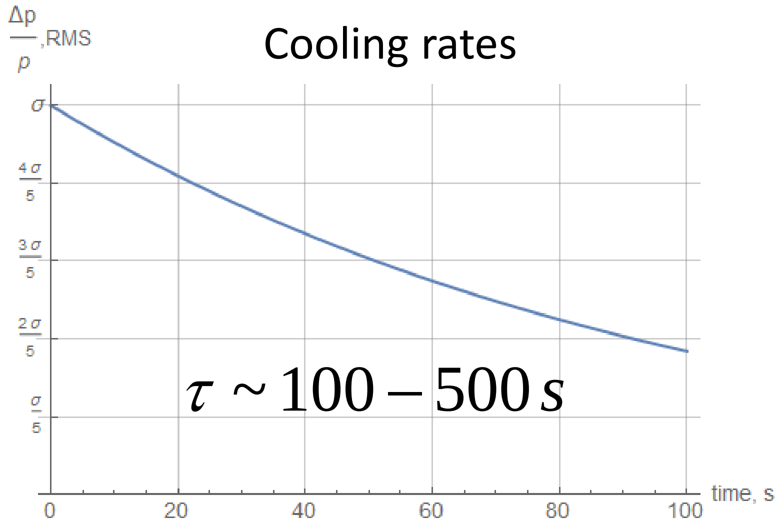
$$F(E)= f_0\Delta E_c \sim \prod_j TF_j$$

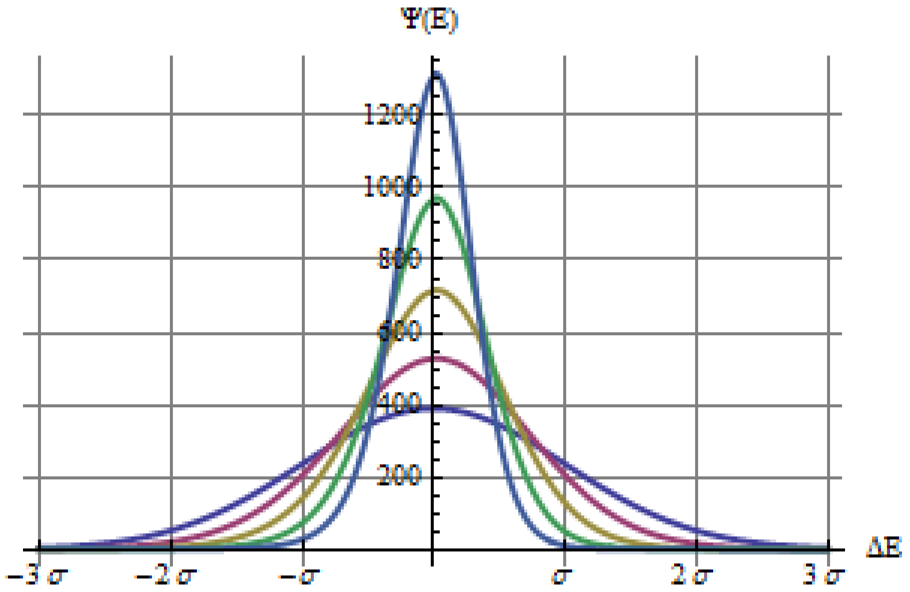
Diffusion term

$$D(E,t)=\frac{1}{2} f_0\left\langle \Delta E_{ic}^2\right\rangle \sim \prod_j TF_j^2$$









NICA collider

Low intensity: Beam accumulation
Short bunch formation
Luminosity preservation: IBS counteraction

NICA collider	
C, m	503
E, GeV/u	1-4,5
Ions	p,d,heavy
W, GHz	2-4
P, Watt	500/channel
Cooling method	Filter, Palmer

HESR(FAIR)

Low intensity: Beam accumulation
Luminosity preservation: Suppression of heating from target

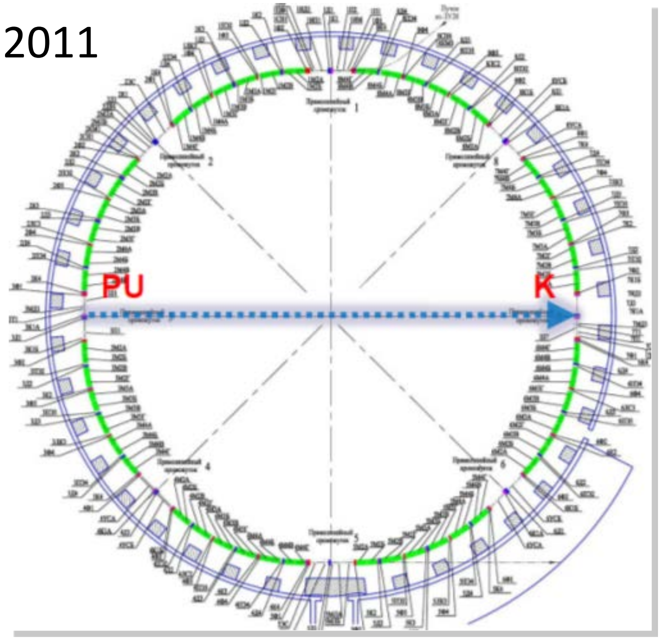
HESR	
C, m	574
E, GeV/u	1,5-15
Ions	p-bar,heavy
W, GHz	2-4
P	500/tank
Cooling method	Filter

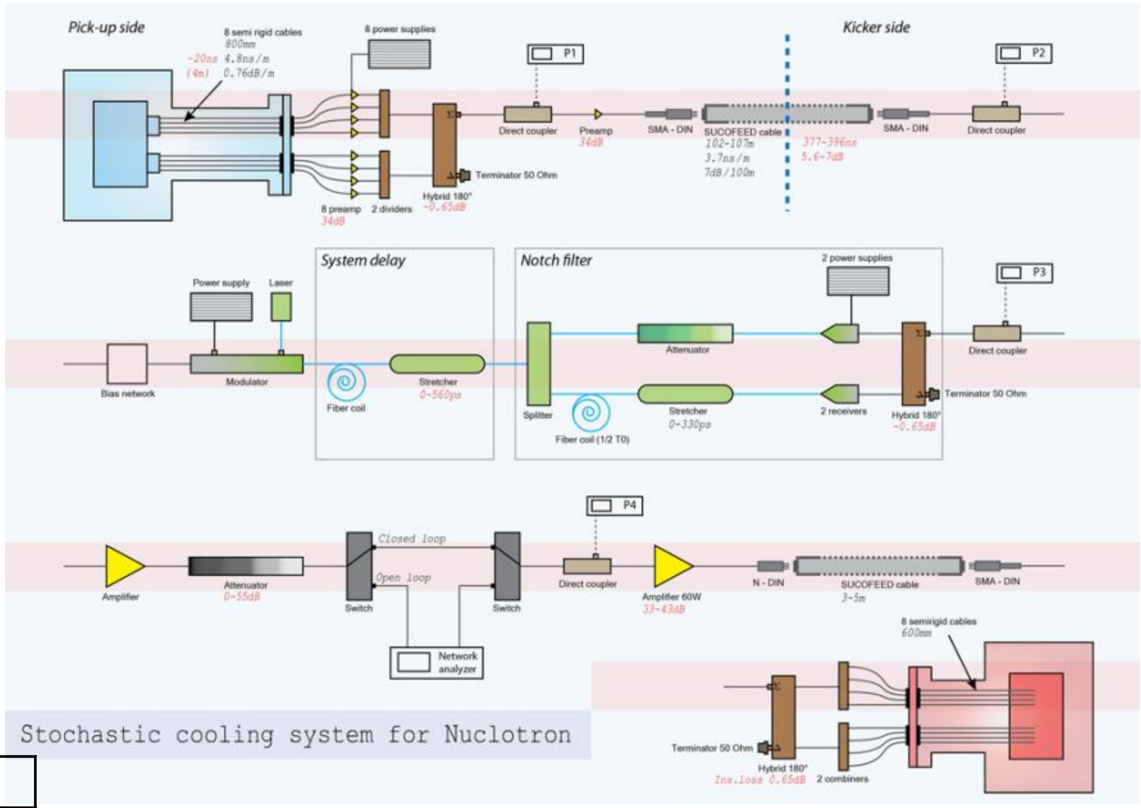
Both NICA & HESR have barrier bucket beam accumulation system

Beam stacking with Barrier Bucket and cooling

Stochastic Cooling experiment at Nuclotron, JINR

Since 2011





Circumference, m	251.5
Ions	up to A=142
Energy, GeV	3.5
Rev.frequency, MHz	1.2
Vacuum, Torr	10^{-9}
Intensity	10^{10}(d)-10^{9}(C)
Ring slippage factor	0,0322
dp/p	10^{-4}

Band 2 – 4 GHz

Output power up to 60 W

Goals:

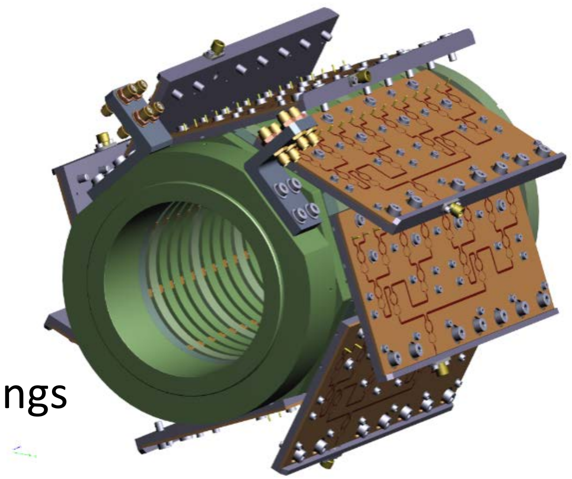
Investigation of different cooling methods

Test of equipment for the NICA collider

Beam parameter measurement(PU) and control(KK)

NICA collider Stoch. cooling	
W, GHz	2-4
Aperture, mm	90
P, Watt	500/channel
Cooling method	Filter, Palmer

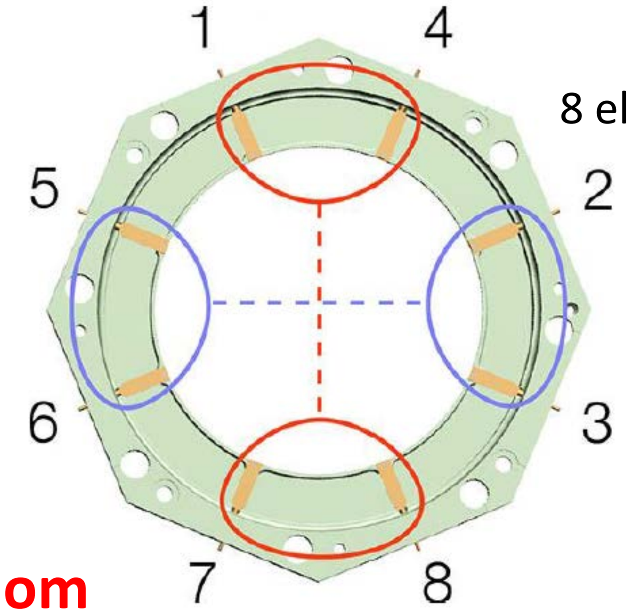
HESR Stoch. cooling	
W, GHz	2-4
Aperture	90 mm
P, Watt	500/tank
Cooling method	Filter



16 rings

Slot-coupler structures, manufactured at IKP FZJ

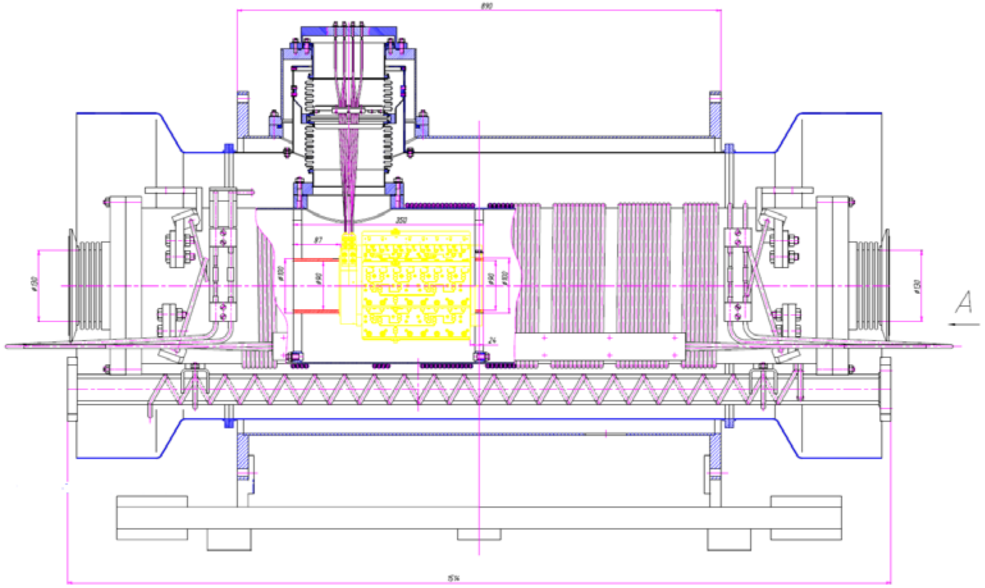
Designed by R. Stassen

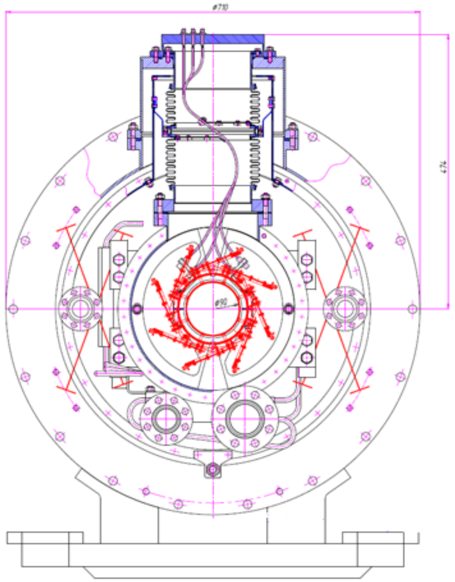


8 electrodes

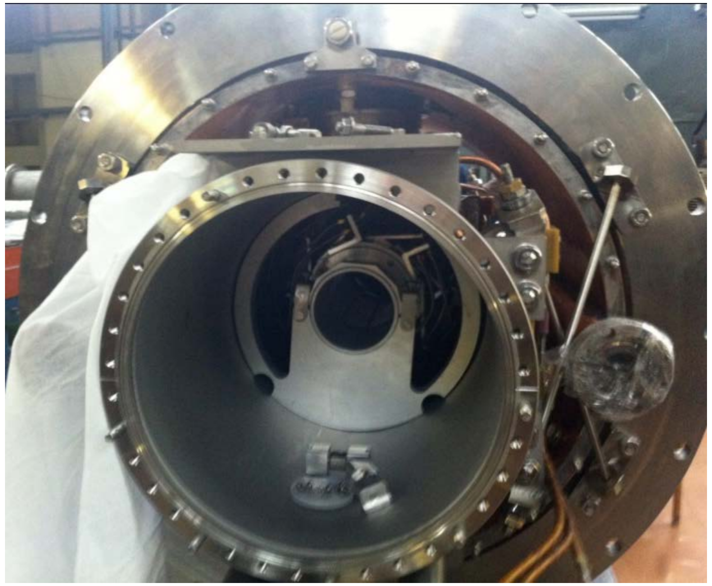
Larger impedance

Universal for 3 degrees of freedom

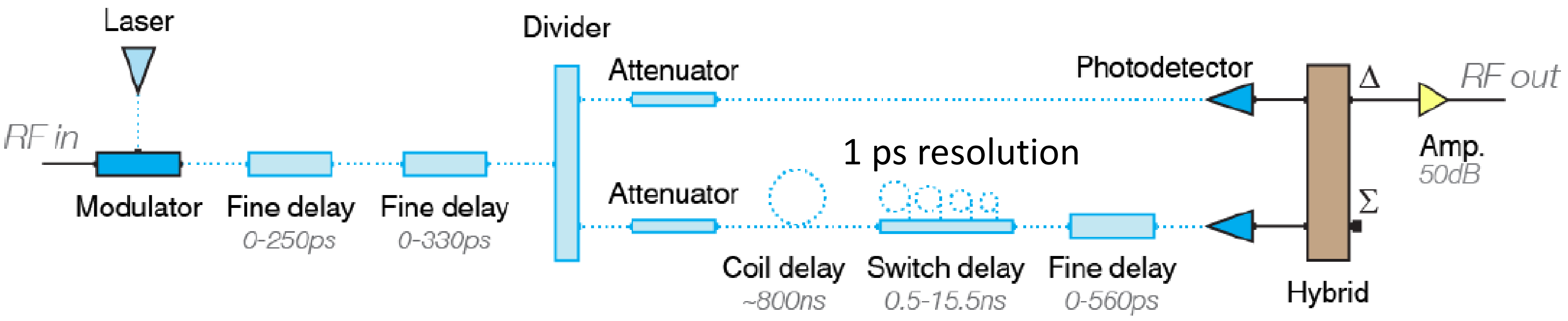


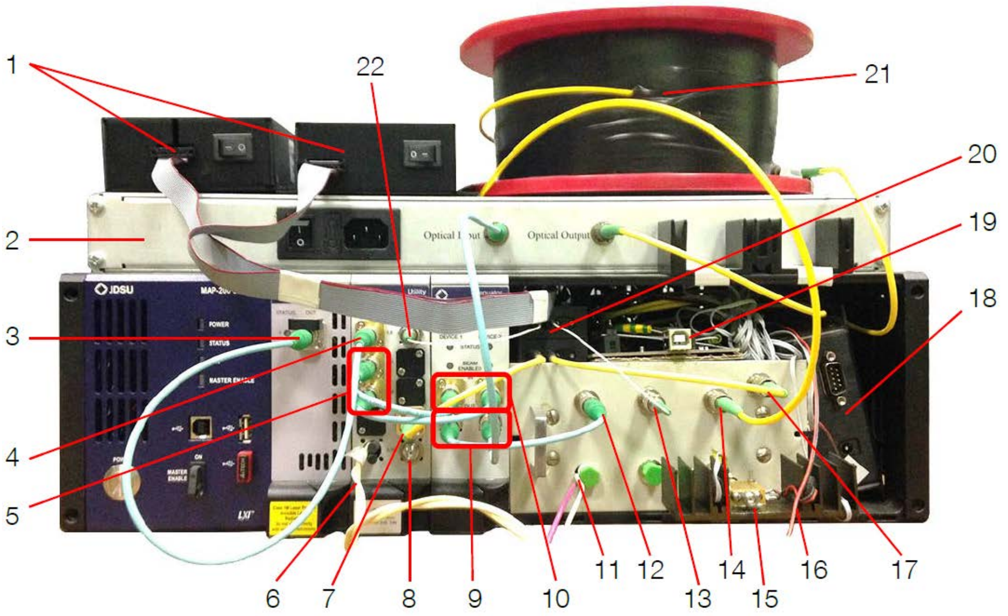


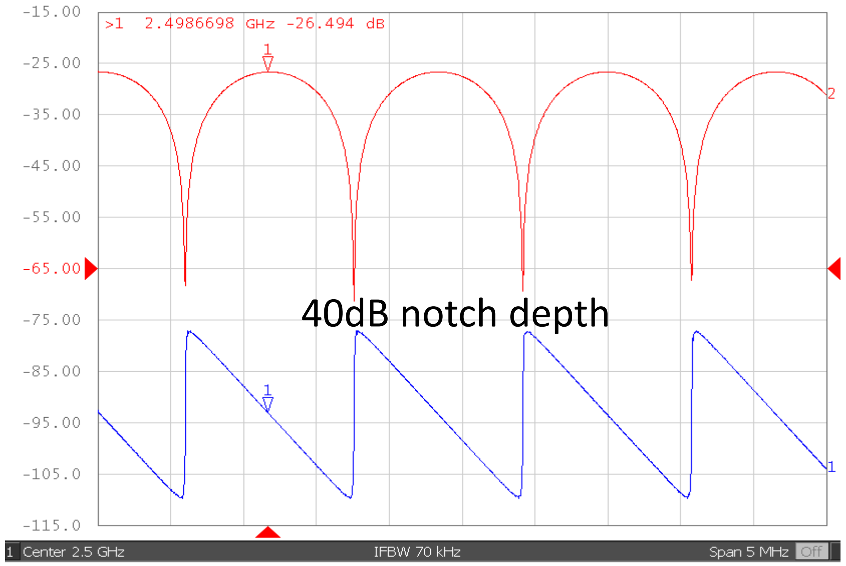
2009-2011
Cryogenics and vacuum tank were designed, manufactured and tested in collaboration with FZJ



Nuclotron SC: Optical notch-filter and delay

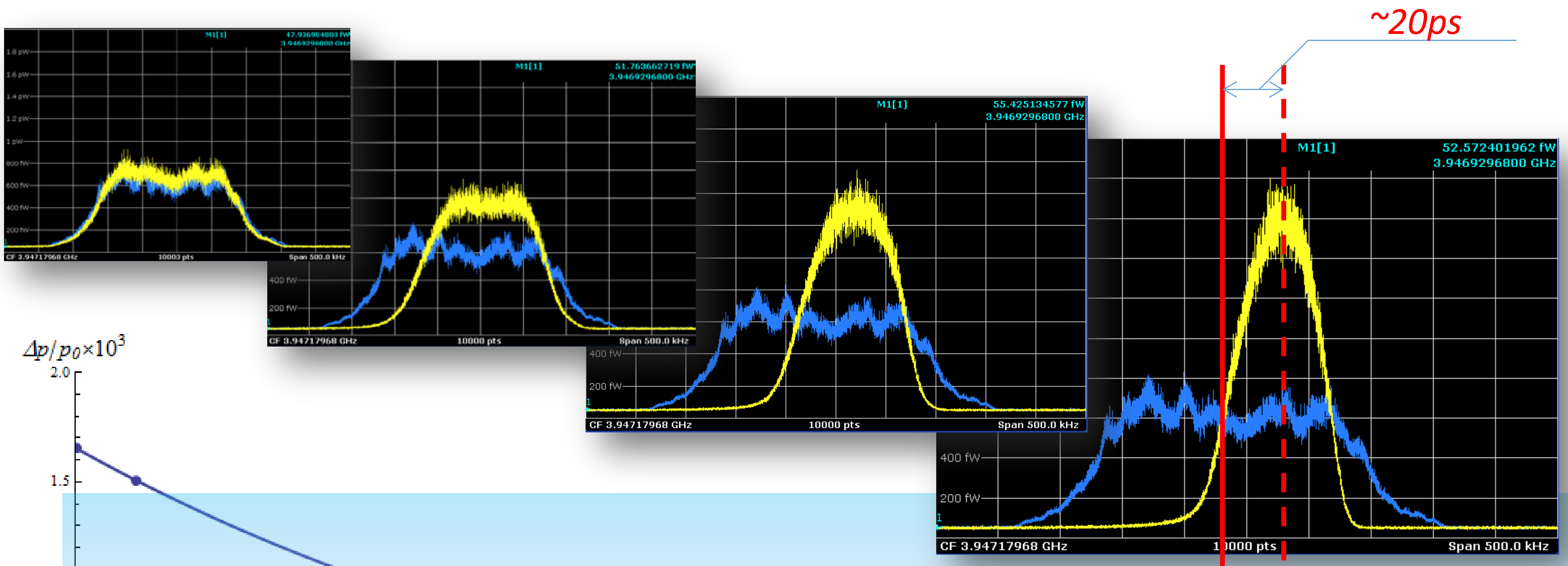


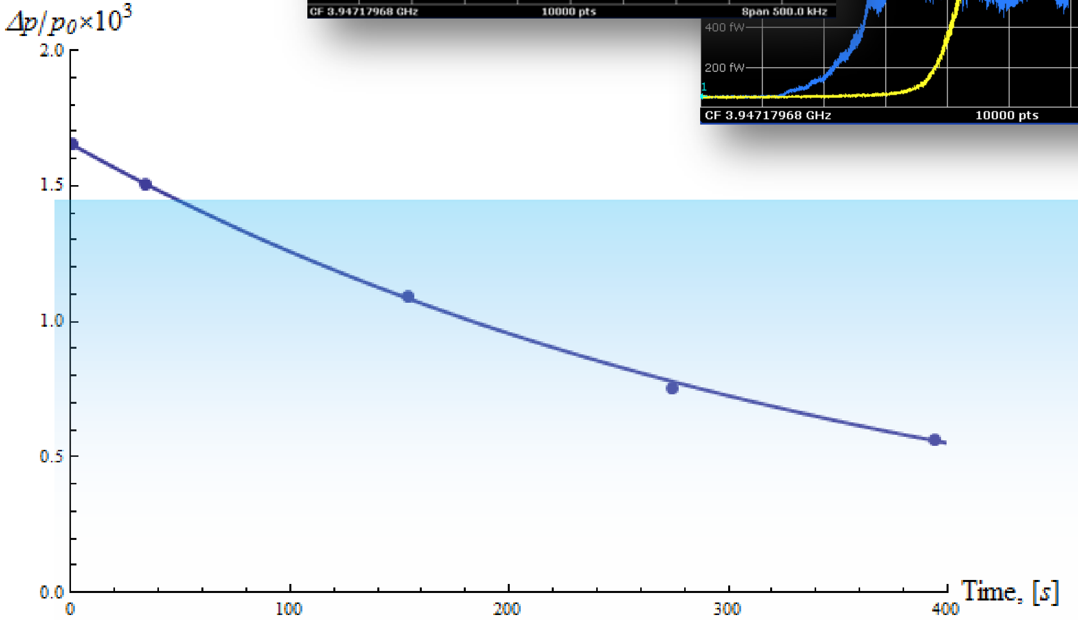




March 2013

First Nuclotron stochastic cooling of coasting D beam





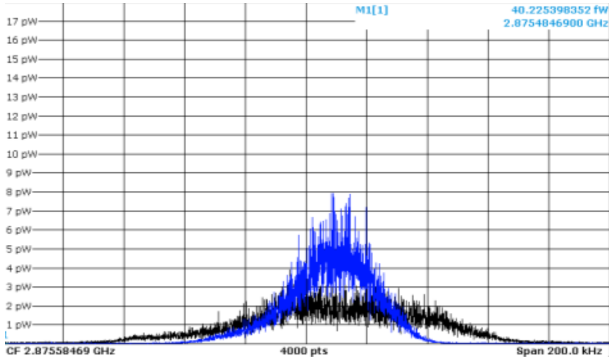
- Cooling period: *480s*
- dp/p (1e-3): *0.55 -> 0.25*

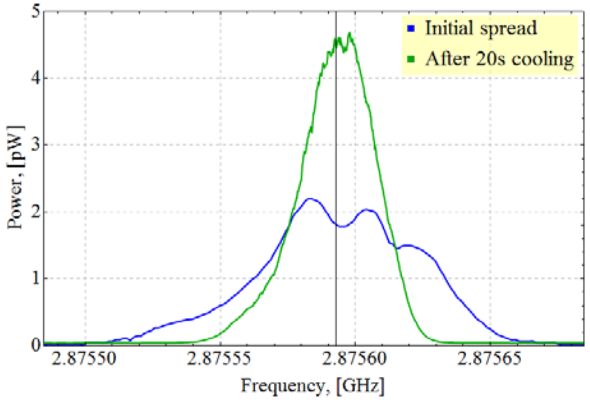
December 2013

Stochastic cooling of the carbon beam 2.5GeV/u

Spectrum analyzer | Computer reconstruction

Coasting beam



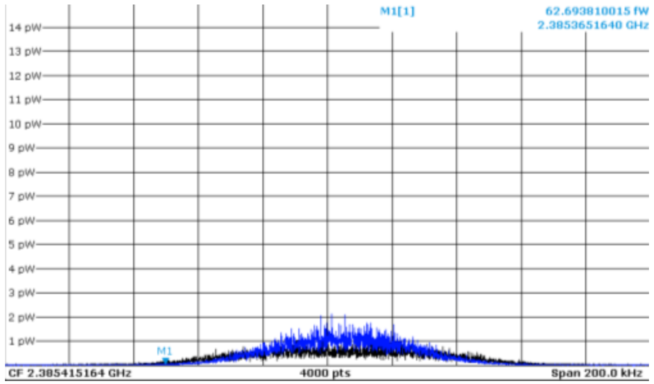


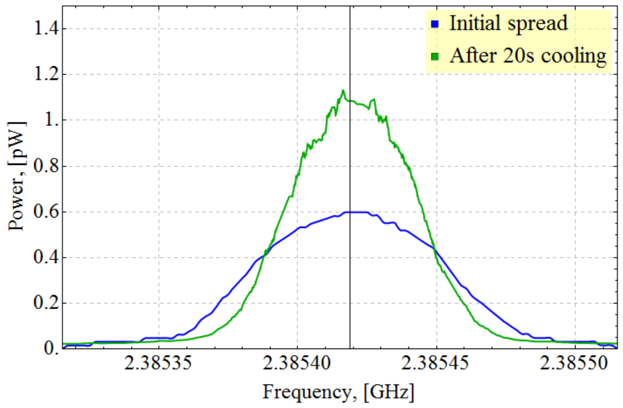
$$\sigma_{init} = 0.15 \times 10^{-3}$$

$$\sigma_{final} = 0.07 \times 10^{-3}$$

$$\tau \approx 27s$$

Bunched beam





$$\sigma_{init} = 0.2 \times 10^{-3}$$

$$\sigma_{final} = 0.13 \times 10^{-3}$$

$$\tau \approx 64s$$

σ_s = 4.2 m

Ring-slot-coupler structure(FZJ) was successfully tested as a kicker at Nuclotron, JINR

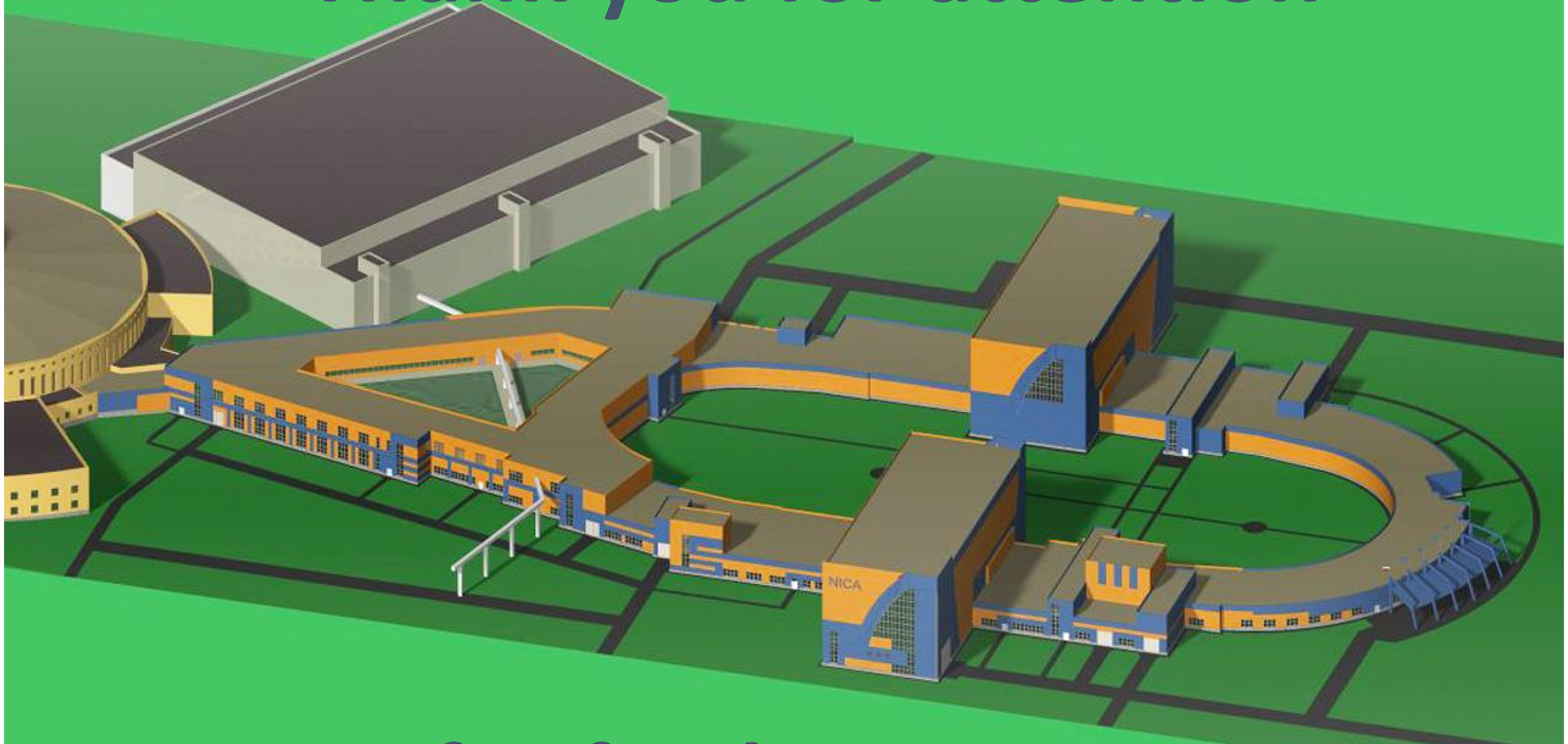
Equipment requirements

Bandwidth	2 – 4 GHz
Aperture	90 mm
Vacuum requirements for pick-up and kicker vessels	10^{-10}-10^{-11} Torr
Number of pickups	6
Number of basic structures per pickup (basic structure = 16 rings)	2
Pickup operational temperature	15 – 20 K
Number of kickers	4
Number of basic structures per kicker	4
Kicker operational temperature	300 K
Total RF power of amplifiers	3 kW
Number of separated 80 W modules (including reserve)	45

Conclusion

- Stochastic cooling is one of the crucial elements of NICA & HESR
- Test stochastic cooling channel was put into operation at Nuclotron, JINR in cooperation with FZJ
- System components were developed and tested in cooperation with GSI,FZJ,CERN,FNAL
- FZJ Ring-slot-coupler was successfully implemented as a kicker for the first time at Nuclotron, JINR
- The basic structure was earlier developed in FZJ for HESR, for the NICA SCS no new design needed. The same structures are under fabrication in FZJ for HESR SCS and the technology satisfies to the NICA requirements. Therefore preferable provider of the SCS elements is FZJ.

Thank you for attention



Hope for further cooperation