Stochastic cooling experiments at Nuclotron and application to NICA collider

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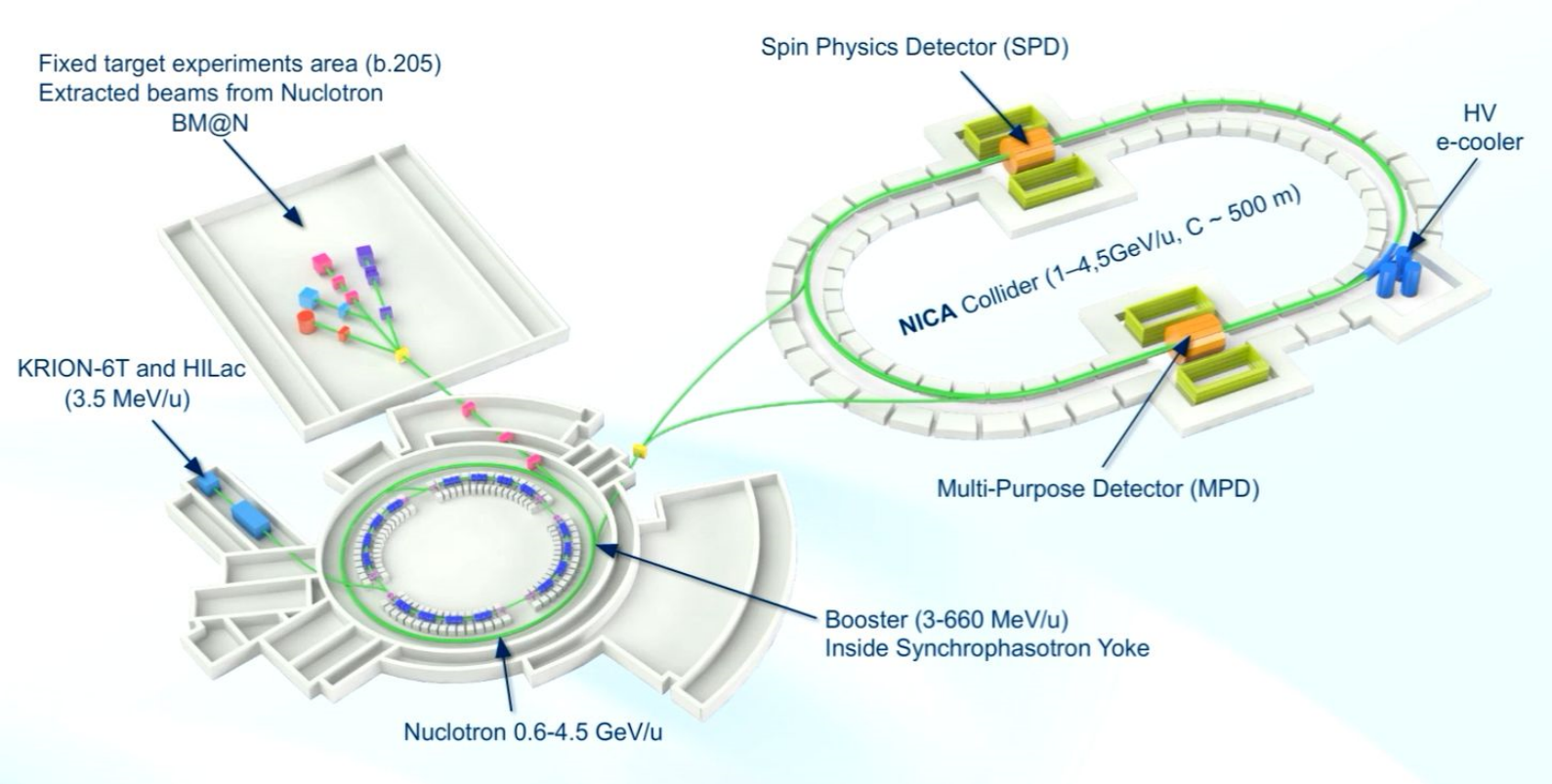
NICA facility

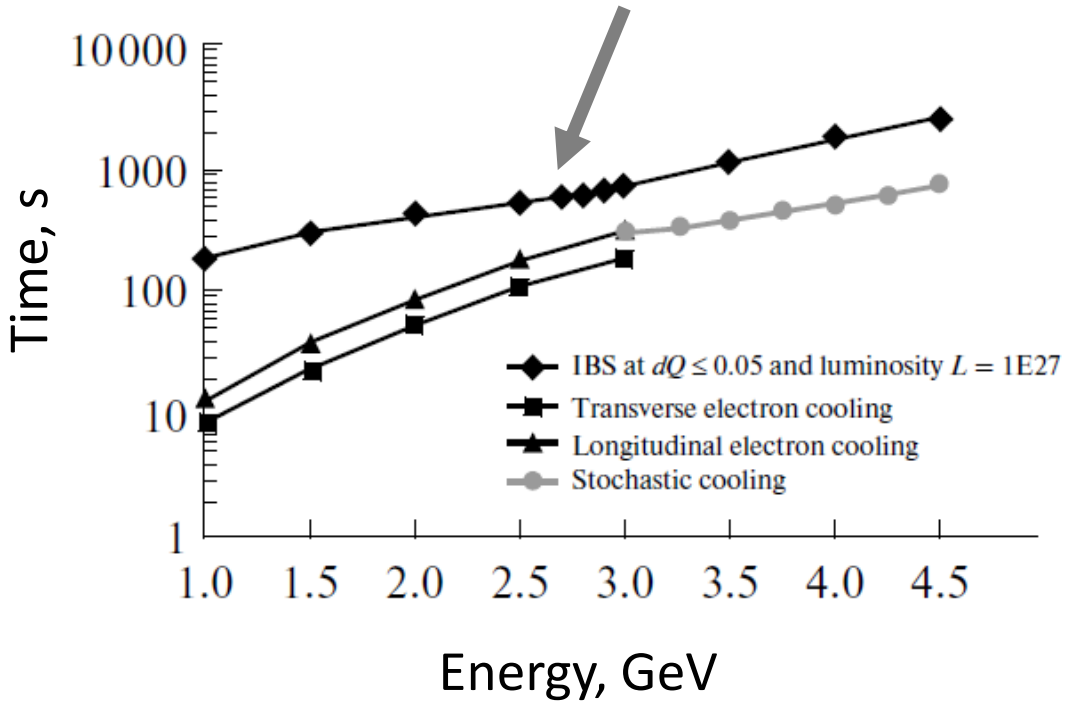


Stochastic cooling is required for:

- ❑ Beam accumulation
  Low intensity
- ❑ IBS counteraction
  3D bunched beam cooling

Challenge

IBS heating times



$$\tau_{IBS} \approx 200\ s, \quad (1\ GeV/u)$$
$$\tau_{IBS} \approx 700\ s, \quad (3\ GeV/u)$$
$$\tau_{IBS} \approx 2000\ s, \quad (4.5\ GeV/u)$$

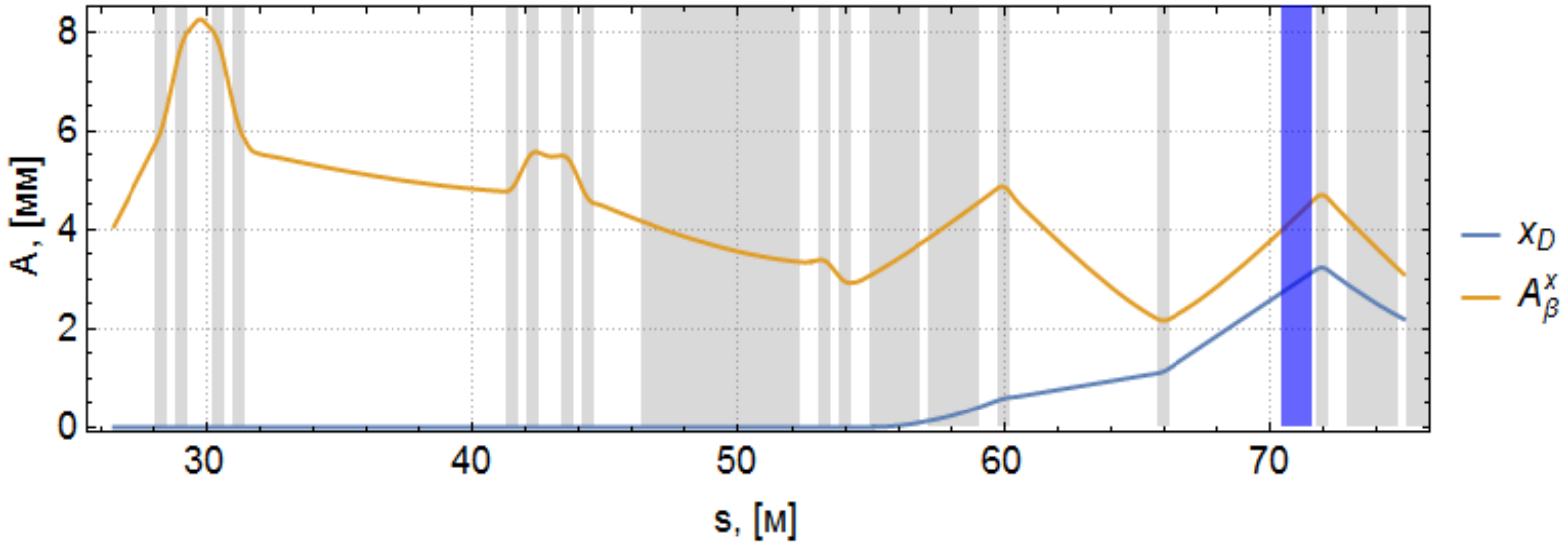
Tasks:
for stochastic cooling

- ❑ Cool faster than IBS-heating
- ❑ Cover widest possible energy range
  At low energies slip-factors become large
  and momentum spread acceptance is reduced

Longitudinal cooling

~~ToF~~ Widest momentum spread acceptance
but wide spread needed
Cooling for > 3.0 GeV/n

Palmer Low dispersion + betatron signal of same order
Cooling for > 3.0 GeV/n

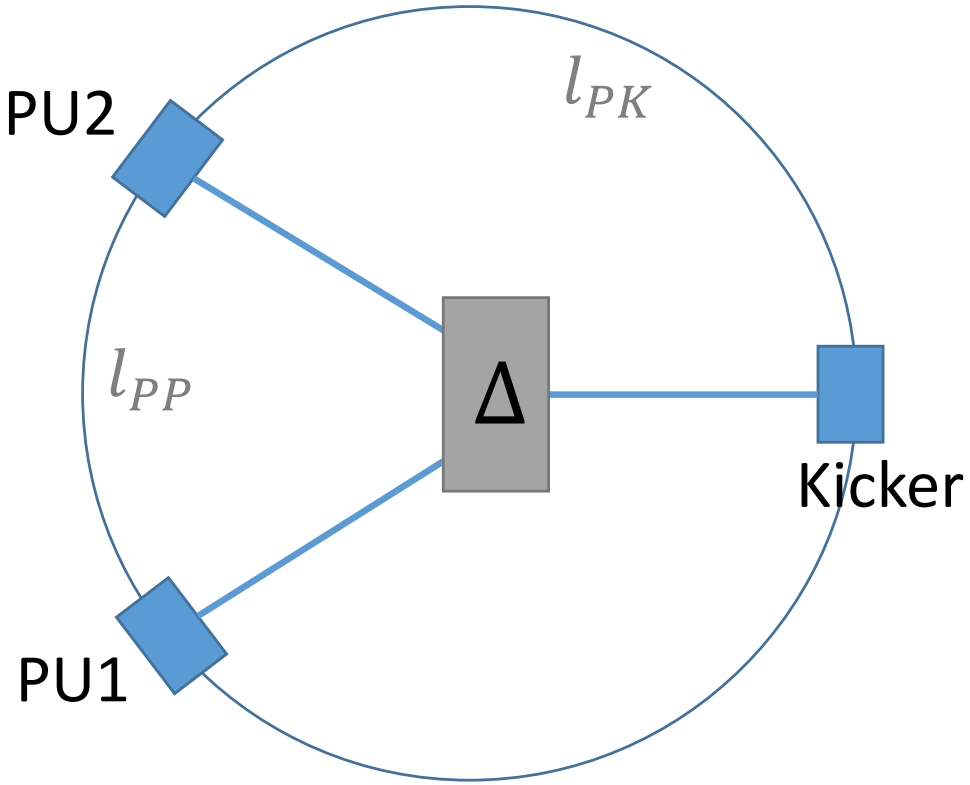


Filter Cooling only for > 4.0 GeV/n

Möhl's method

IDEA: $Correction \sim PU_{\Sigma}^{1} - PU_{\Sigma}^{2}$

Correction signal is proportional to the difference of signals from 2 spaced longitudinal pick-ups

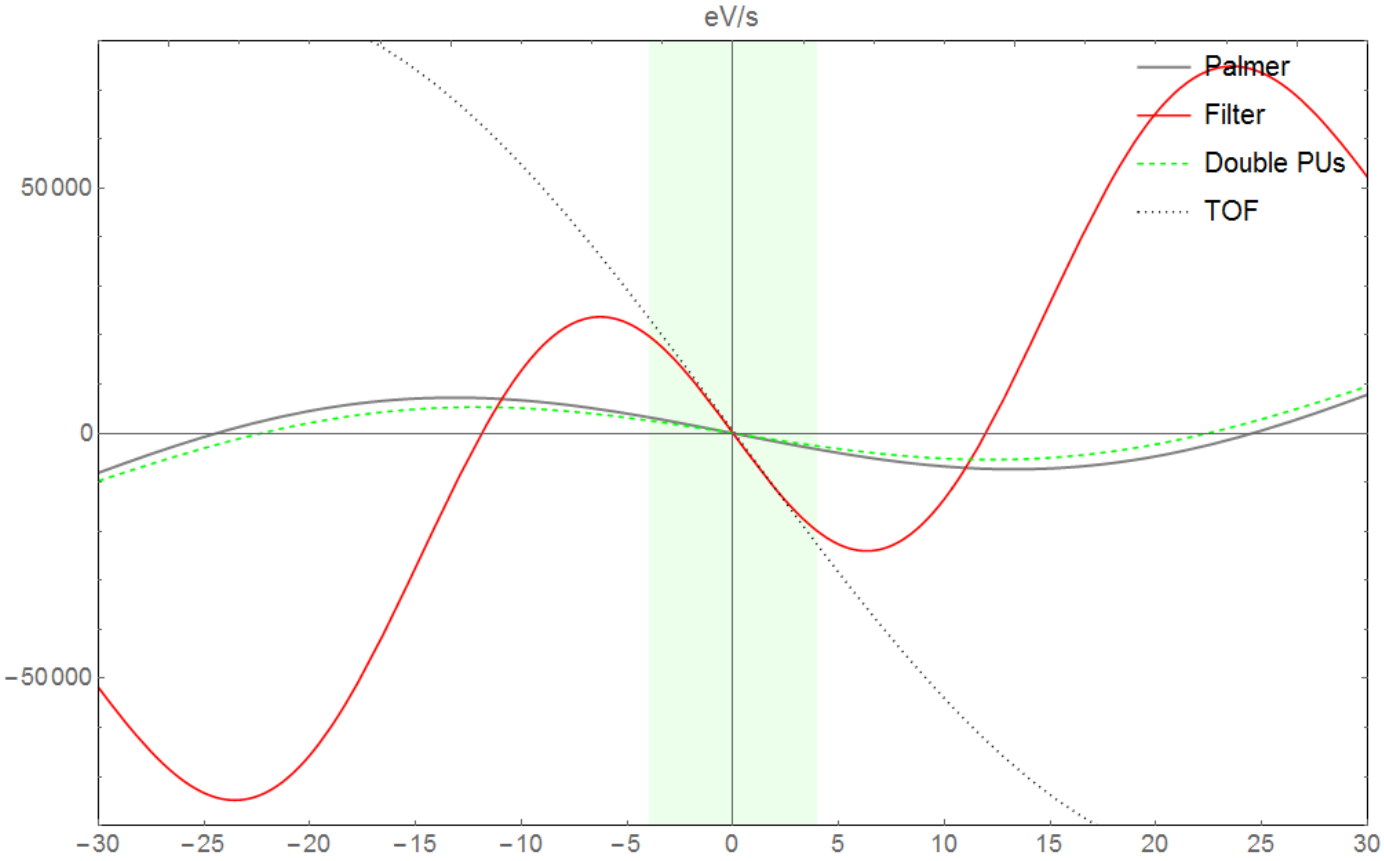


Momentum spread acceptance is proportional to the distance between pick-ups (l_{PP}):

$$\left(\frac{\Delta p}{p}\right)_{Max} \sim l_{PP}$$

$l_{PP} = 0 \rightarrow Palmer$
$l_{PP} = ring\ length \rightarrow Filter$

Momentum acceptance comparison

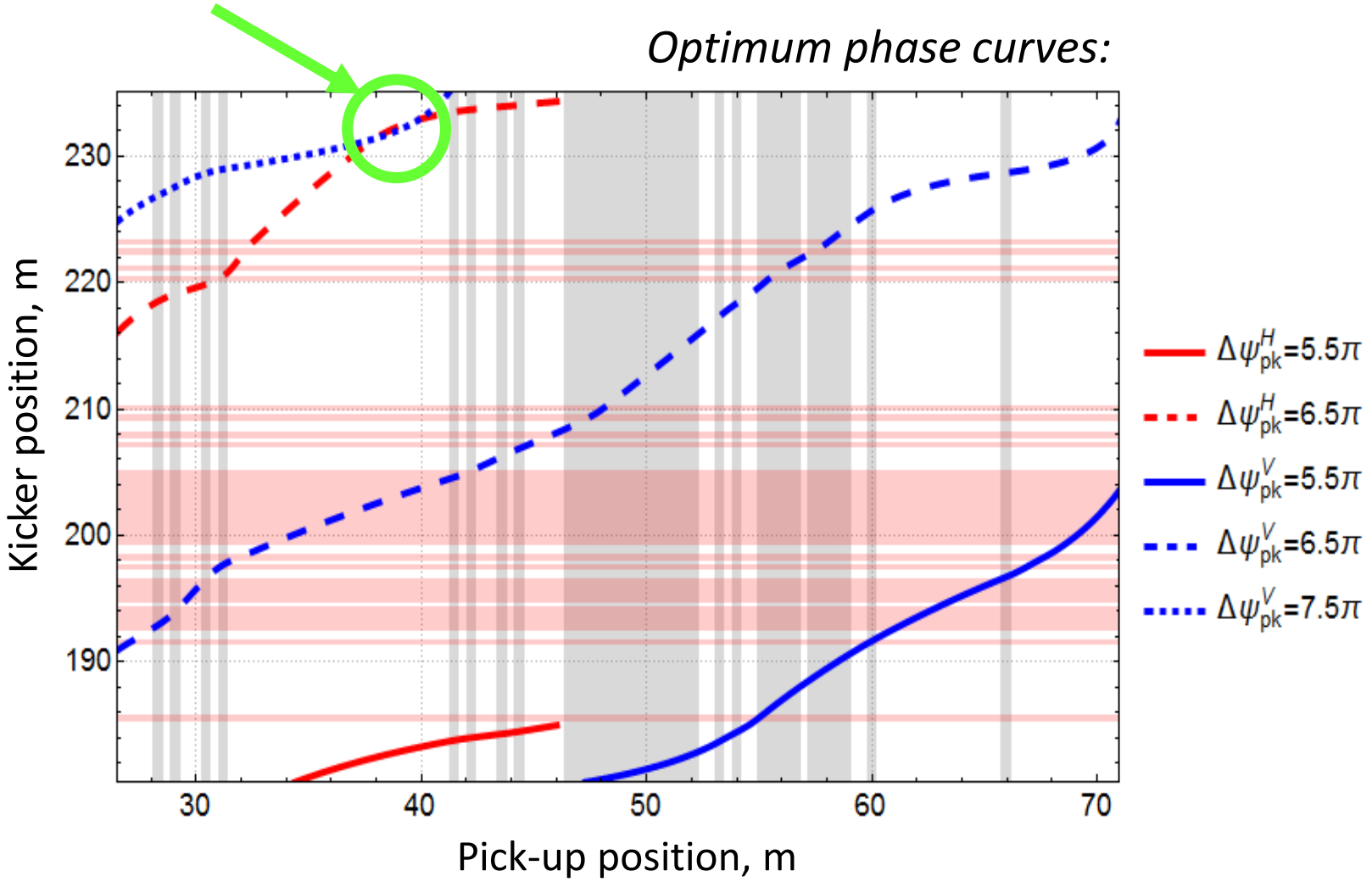


Mohl's method allows to cover entire IBS-dominated regime 3-4.5 GeV/u

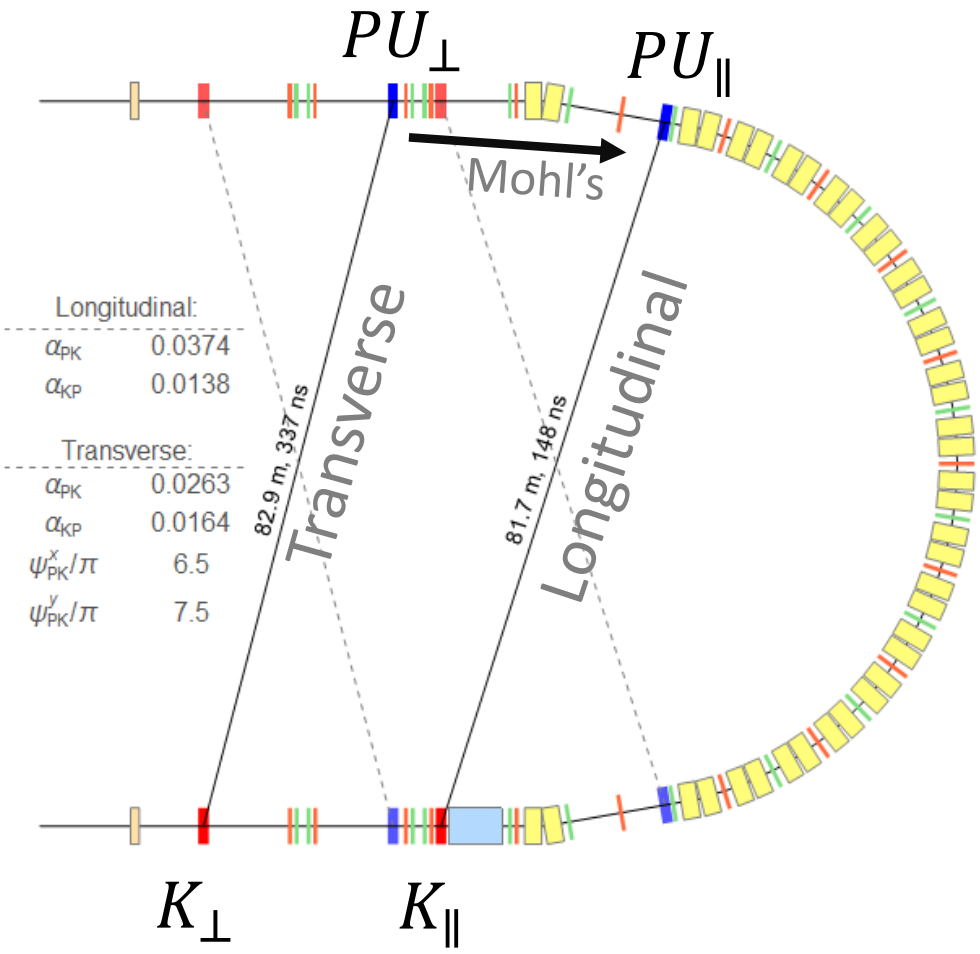
Transverse cooling

"Merged" transverse systems are preferred

(i.e. using same PU and KK)



Proposal for NICA

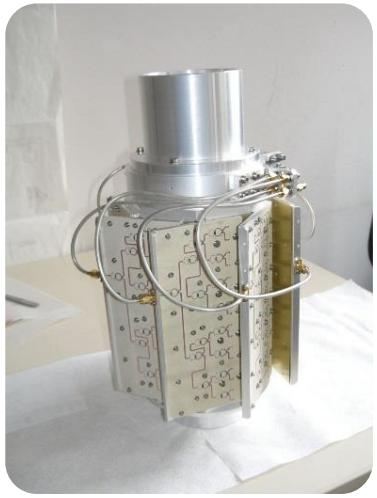


Bandwidth: 2-4 GHz
Energies: 3-4.5 GeV/u
Amp. Power: < kW

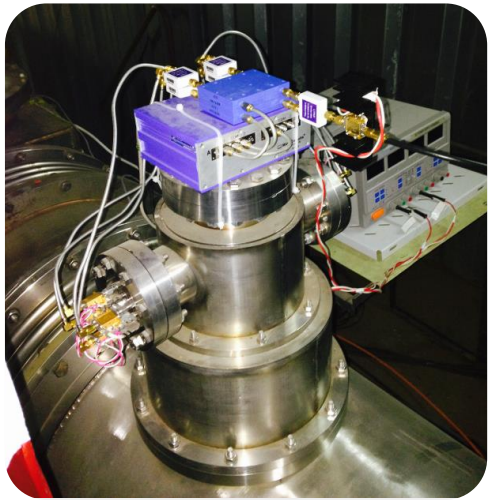
NICA start version:

- ❑ Only longitudinal cooling at fixed energy
- ❑ 200W TWT amplifiers from FNAL

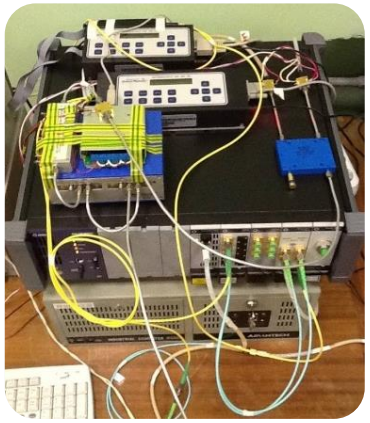
Stochastic cooling at Nuclotron



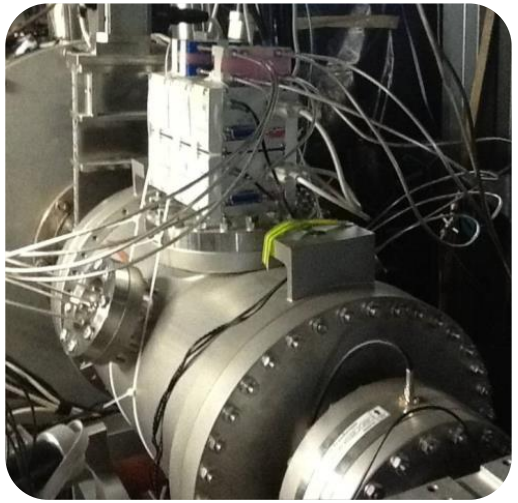
Ring-slot coupler (FZJ)



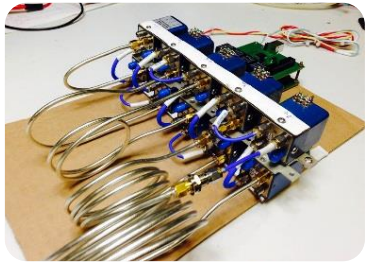
PU electronics



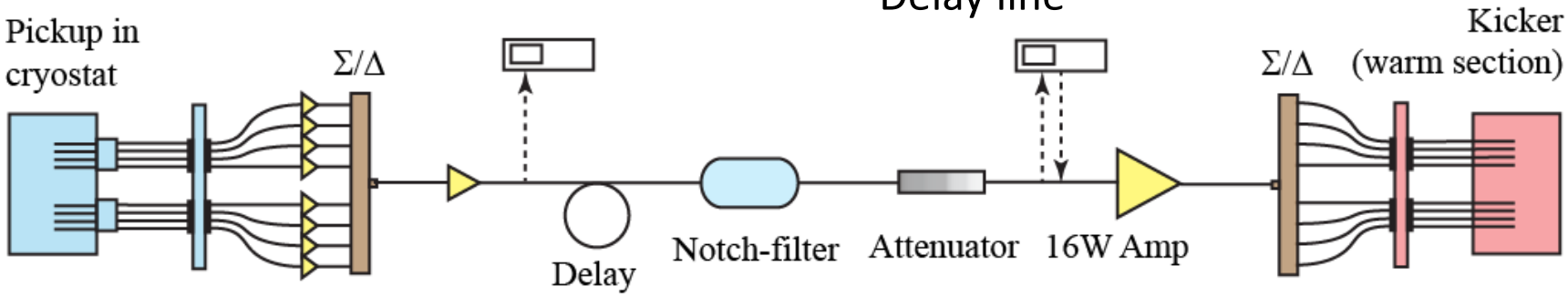
Notch-filter



KK electronics

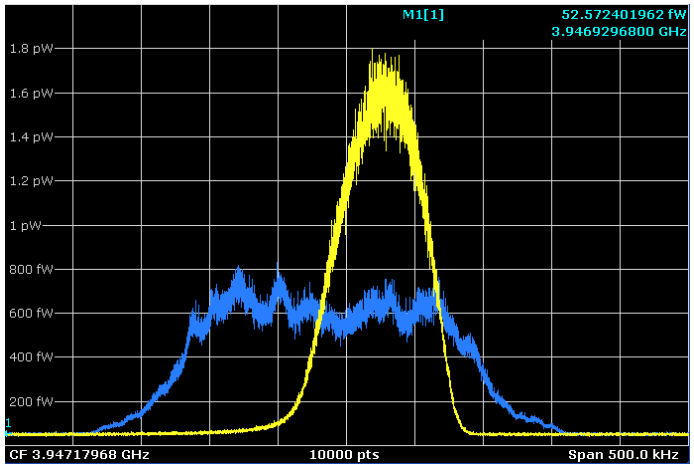


Delay line



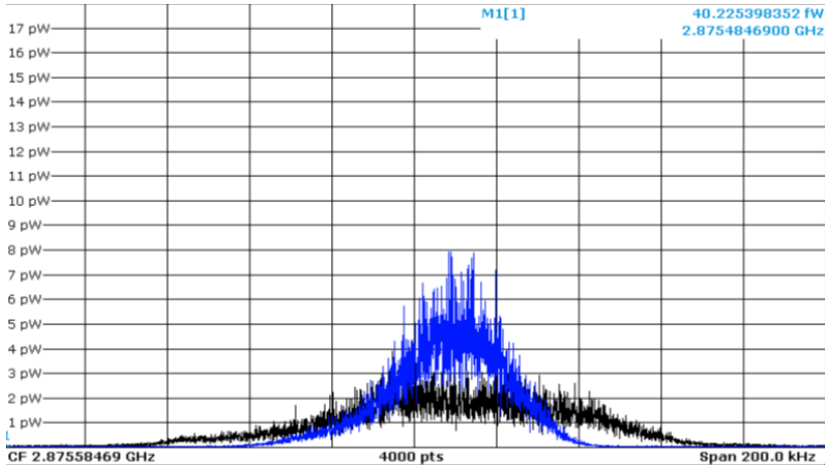
Longitudinal (notch-filter), 2-4*GHz*, 60*W*:

Experimental results



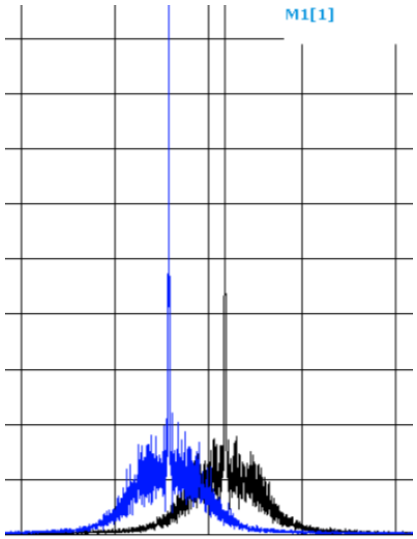
2×10^{9} D^{+}, 17W amplifier

$\tau_0 = 480s$

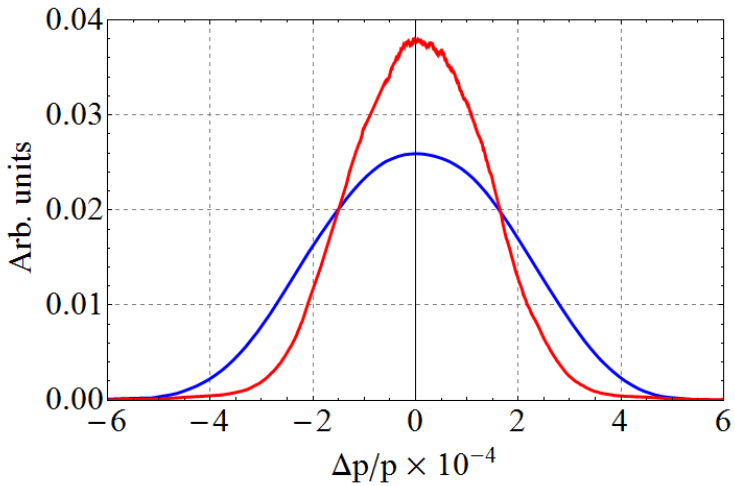


2×10^{8} C^{6+}, 60W amplifier

$\tau_0 = 28s$



Bunched-beam Schottky

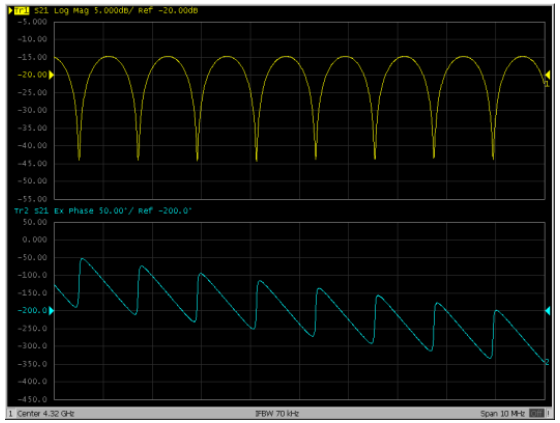


2×10^{8} C^{6+}, 60W amplifier, 2.5 bunches

$\tau_0 = 64s$

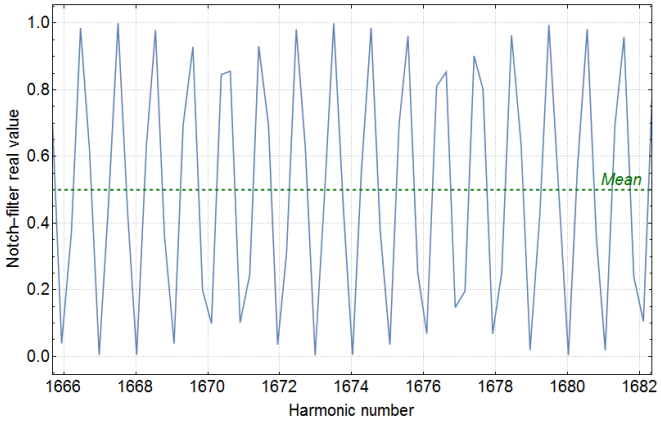
“Magic” button

- Notch-filter



Automatic notch-filter adjustment

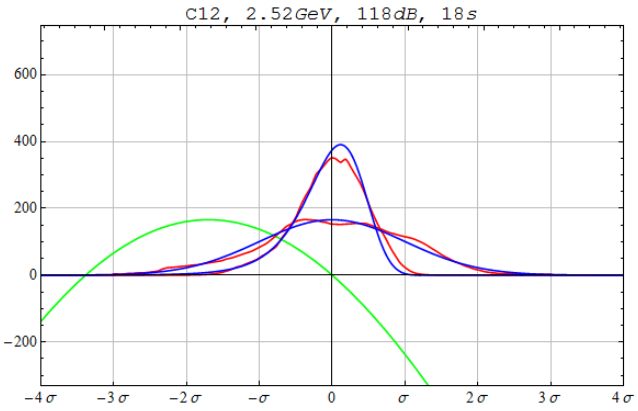
From hours to seconds



- Open-loop measurements

- Self-adjustment by feedback via parallel “simulations”

  (Analysis of distribution evolution patterns)



Conclusion

- Mohl's method was investigated and proposed for the collider
- TDR of stochastic cooling system for NICA collider was worked out
- The prototype longitudinal notch-filter system was built and tested at Nuclotron
- A number of automation algorithms were developed

Thank you!