



# Plans for Collider Commissioning and Polarization

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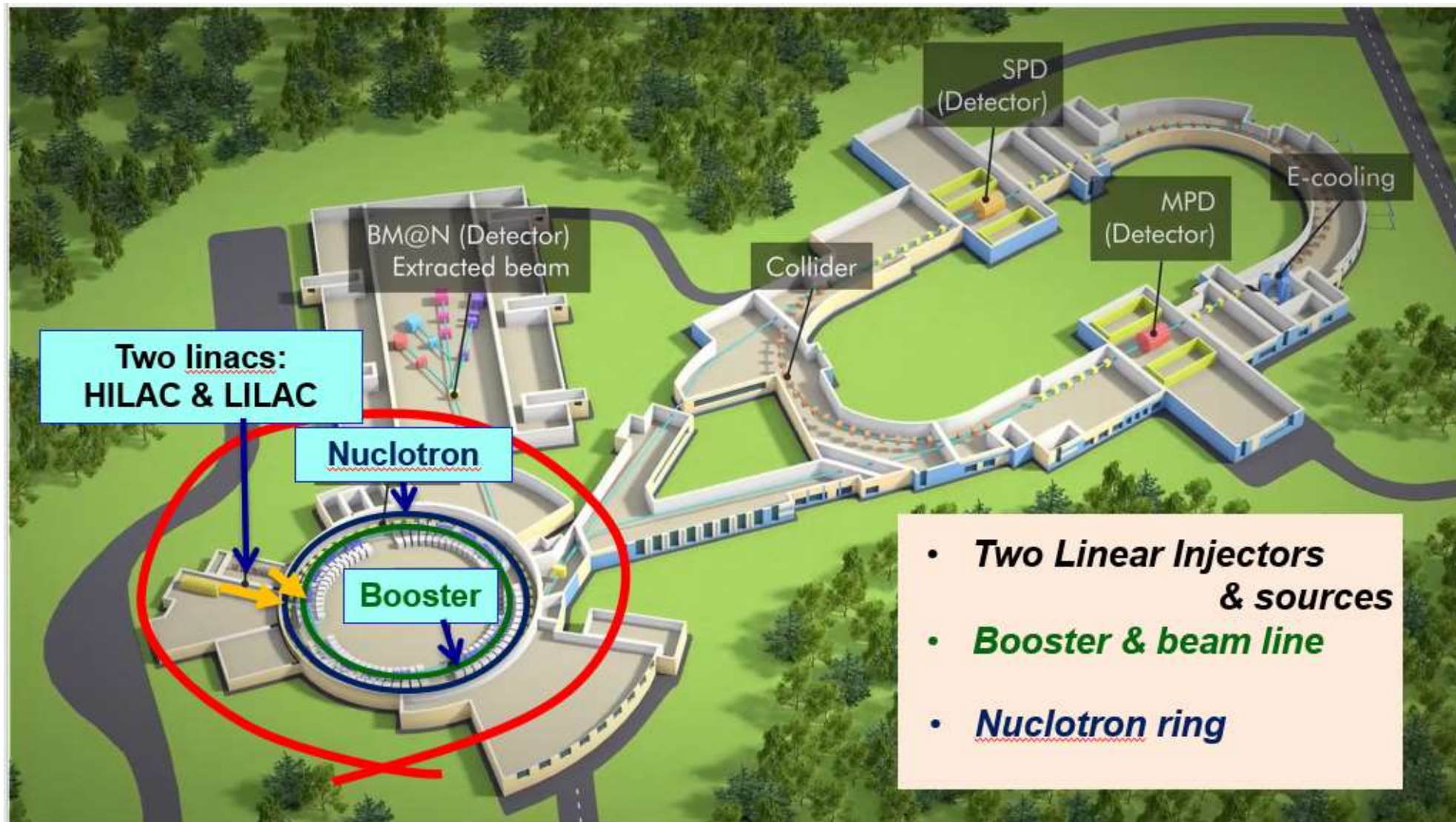
JINR

“Поляризованные источники,  
поляриметрия, спиновая физика  
высоких энергий на Ускорительном  
комплексе ЛФВЭ ОИЯИ”

Oct. 30-31, 2024

JINR

# NICA Collider Complex Layout

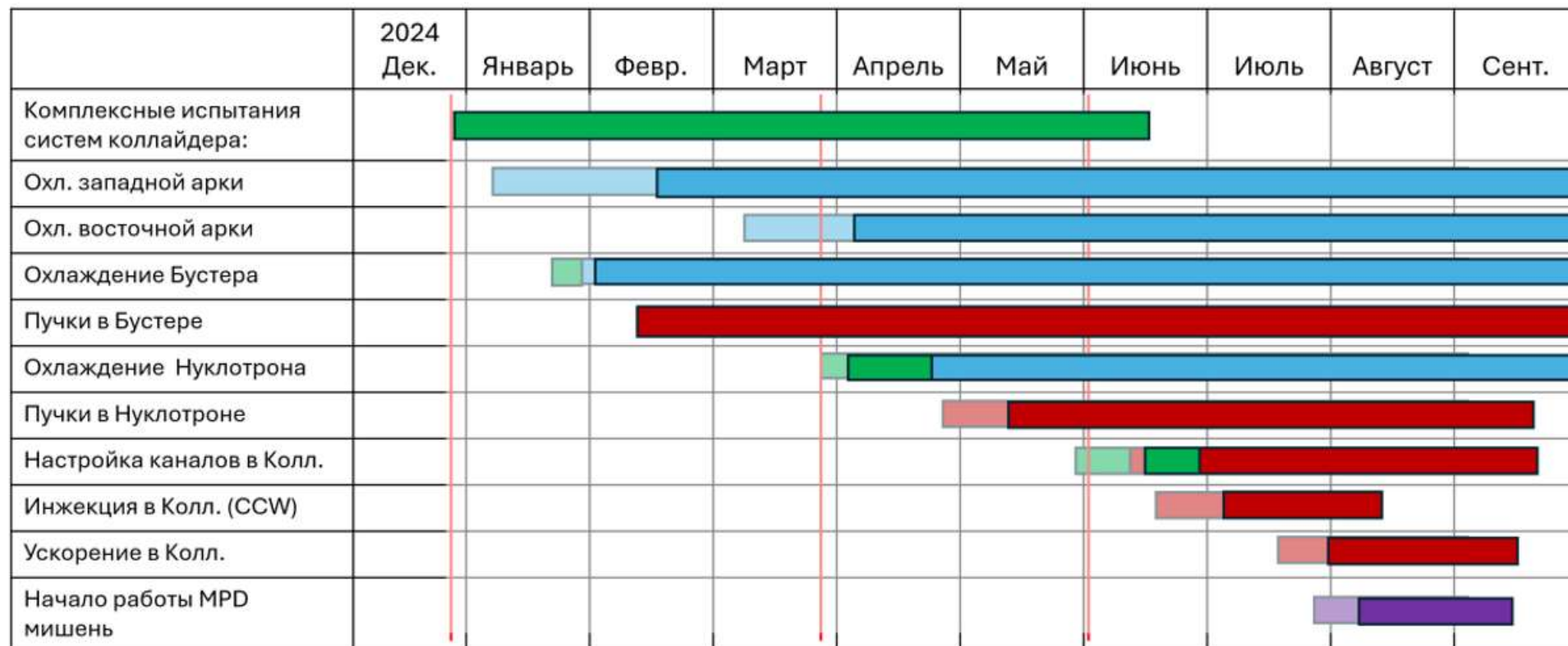


# Priorities for the Accelerator Complex

1. Most of NICA commissioning will proceed in heavy ion mode
  - ◆ “Real” luminosity is expected in 2.5 – 3 years
    - after we will get cooling systems operational
2. Operation with slow extracted beams
  - ◆ All modes of operations are anticipated
    - Heavy ion mode is straightforward – it will not require significant efforts (Xe is at the beginning)
    - Light unpolarized ions will be a backup for heavy ion mode in the case of problems with KRION (Acceleration in Booster)
    - Polarized ions  
(Acceleration in Nuclotron, LU-20 has to be operational)
    - Medium mass ions from laser source are anticipated  
They will require additional ion source (laser source?)
      - Operation in 2-4 years
- SPD will not come earlier than in 7-10 years
  - ◆ Supporting and development of expertise in operation with polarized beams is the must to be successful with SPD

# Plans for Commissioning of NICA and its Systems

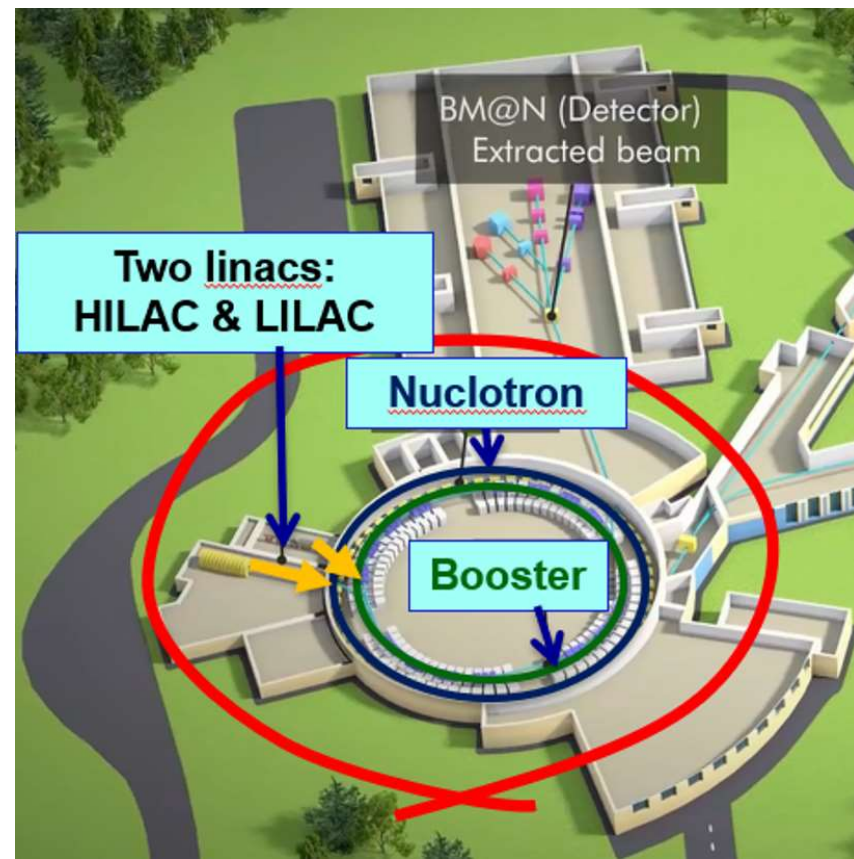
- This plan was presented at the coordination committee meeting, Oct.25, 2024



- Tough and ambitious plan
- Expected that the beam commissioning will start in the summer of 2025
- Beam commissioning of 2 rings will take ~6-12 months
- Then shutdown for 6-12 month to install cooling systems & ...
- Start of operation in the collider mode at or after summer 2026

# NICA Injection Complex Plans

- Injection complex is already in commissioning for few years
  - ◆ Intensity of  $(5-8) \cdot 10^6$  fully stripped Xe ions at the top Nuclotron energy of 3.9 GeV/u was achieved
- The major goal of coming Booster Run is to get to the beam intensities above  $2 \cdot 10^8$  Xe ions at the top Nuclotron energy
- Nuclotron operation is postponed to April-May of 2025
  - ◆ Installation of fast extraction
- We expect beginning of beam delivery to Bldg. 205 and the applications area in the 2<sup>nd</sup> half of 2025
- Improvement of slow extraction efficiency:  $\sim 30\% \rightarrow \sim 90\%$
- Peak Nuclotron field will not exceed 16.5 kG as in Run IV

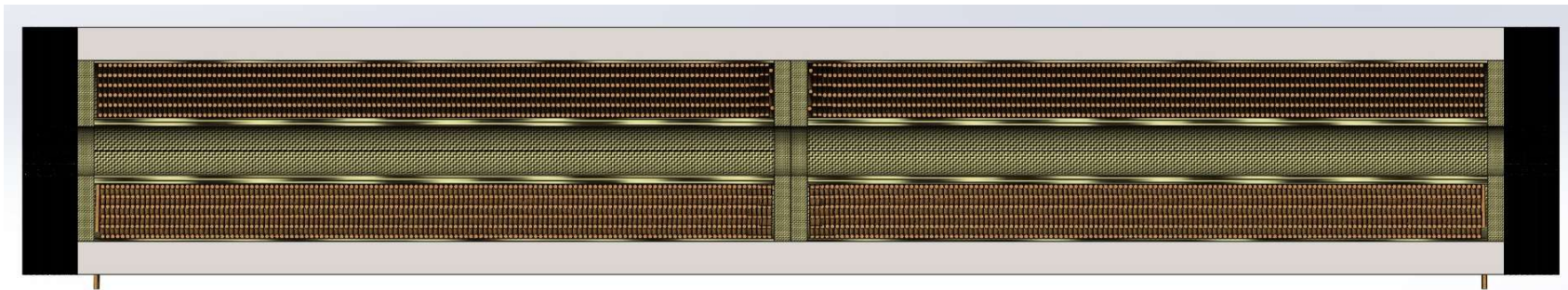
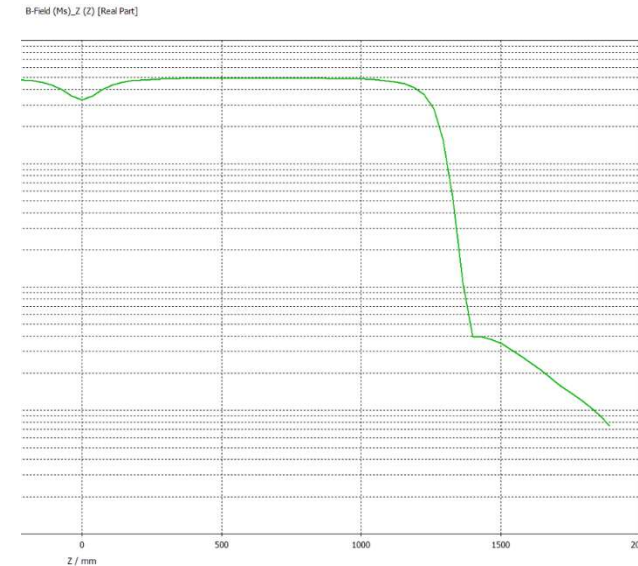


# Plans for Acceleration of Polarized Ions

- Delivery of LILAC (Light ions linac) is postponed to unknown time
  - ◆ LU-20 is the only available possibility for near future
    - LU-20 “switching-on” slowly proceeds
      - Looks like the problem with beam loss is found
      - Consequences of recent accident are addressed
      - I expect LU-20 operations to be resumed by the year end
- Increase of LU-20 acceleration efficiency from  $\sim 10\%$  to  $\sim 30\%$  will trigger displacement of the polarized ion source to LU-20
  - ◆ Nuclotron injection energy - 5 MeV/n
  - ◆ Particle number will be limited by betatron tune shift at  $E_{inj}$  to  $\sim 2.5 \cdot 10^{10}$  for H and  $\sim 5 \cdot 10^{10}$  for D ( $\epsilon_{RMS}=3 \mu\text{m}$ ,  $2.5\sigma_{max}=16 \text{ mm}$ ,  $\Delta v=0.2$ )
- I would not exclude short runs with acceleration of polarized D in the 2<sup>nd</sup> half of 2025
  - ◆ 2026 looks more realistic
- If LU-20 will be out of operation we still can inject polarized D through HILAC and Booster – such operation was recently tested
  - ◆ It will require new line connecting the Ion source and HILAC

# Acceleration of Protons in Nuclotron

- We plan to install SC solenoid into Nuclotron to support proton beam acceleration without loss of polarization
- Presently, two Nuclotron straights are taken by RF cavities
- In the future we want to replace these cavities by SC solenoid and new RF cavities which are identical to the Booster RF
  - ◆ The SC solenoid of  $\sim 2 \times 12$  T m is in advanced stage of design
  - ◆ BINP will be ready to start work on new RF system in the 2nd half of 2025
- Solenoid
  - ◆ Current – 6.9 kA
  - ◆  $B_{\max}$  - 5 T
  - ◆ Stored energy - 640 kJ



# Far Plans are related to the SPD



# *NICA Operation with Polarized Light Ions in the SPD Era*

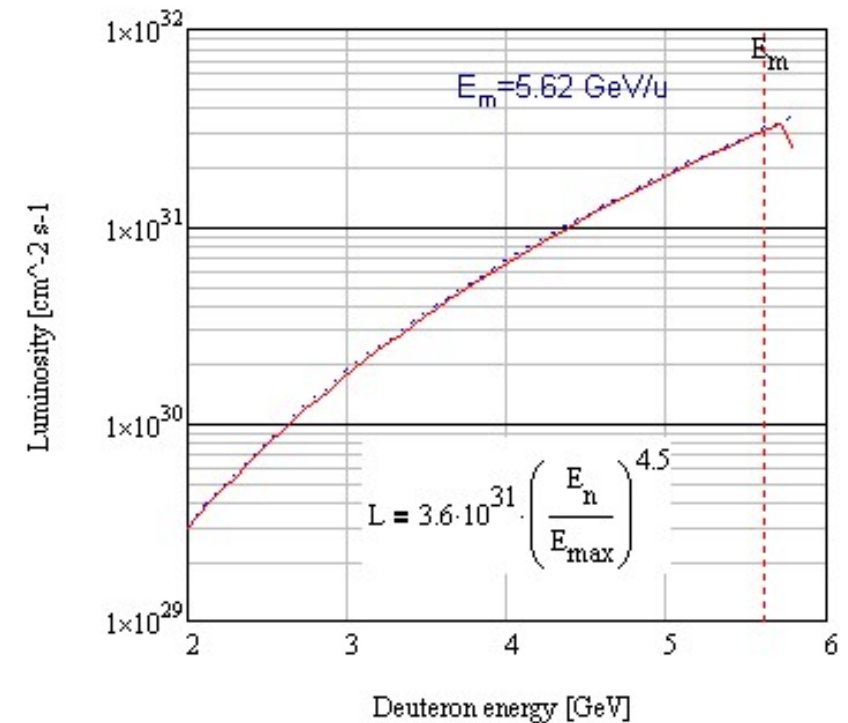
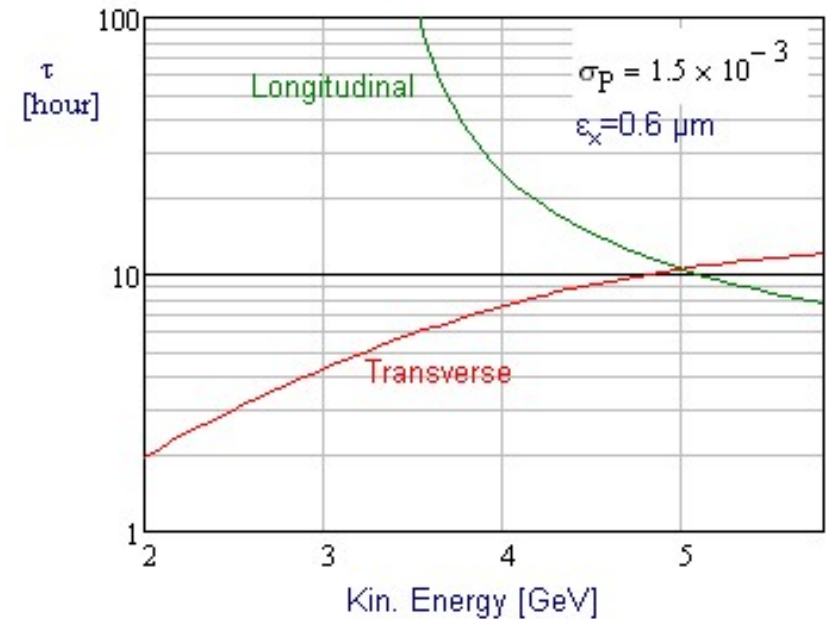
- Two major requirements:
  - (1) Maximum luminosity
  - (2) Maximum polarization
- Main effects/limitations which set the peak luminosity
  - ◆ Beam-beam effects and beam space charge effects
  - ◆ Intrabeam scattering (IBS)
  - ◆ Multipacting and ep-instabilities
  - ◆ Limitations set by already chosen beam optics
  - ◆ Beam coupling impedances, beam instabilities and their suppression
- Many problems will be more challenging
  - ◆ No top energy cooling and larger beam current
- Experience with heavy ions will be greatly helpful for the collider commissioning with polarized ions

# Limitations Set by Present Design of NICA Rings

- All dipoles and quads connected serially
  - ◆ Considerable saving at the machine construction, but only small optics corrections are possible;  $\beta^*=60$  cm  
⇒ Limited transition energy ( $\gamma_{tr}=7.03$ ) variation:
    - on a half way to the maximum energy for protons
    - almost at the maximum energy for deuterons
- We launched an upgrade for independent powering of quads
  - ◆ All straight-line, but IP, quads will be powered separately
    - That requires new quads but will enable a change of the IP  $\beta$ -functions – statically and dynamically
- Reduction of impedance will be required due to larger beam current
  - ◆ Replacement of BPMs in arcs, covering of bellows ...
- For present electron cooling its energy is well below maximum operating energies for both  $p$  &  $D$ 
  - ◆ IBS will result in a loss of both peak luminosity and, in much larger degree, **its integral**

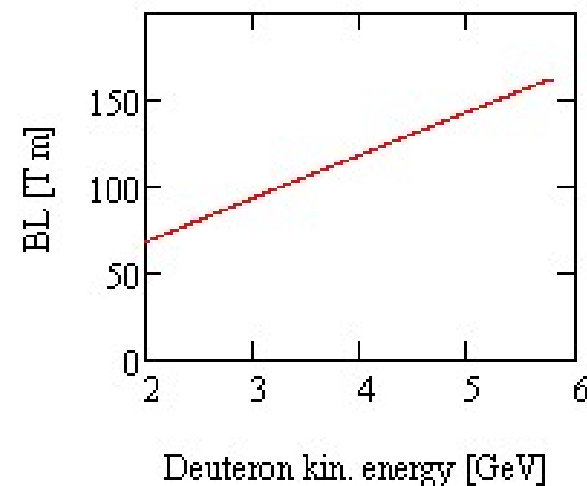
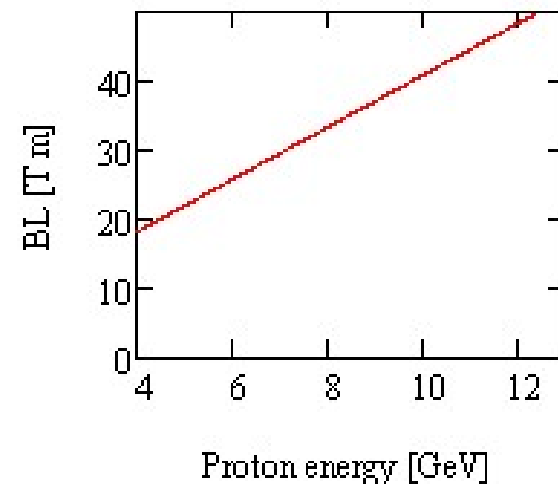
# Operation with Deuterons

- Loss of polarization at the beam acceleration in Nuclotron should not be an outstanding problem even in absence of the solenoid
- Nuclotron can accelerate almost to the top collider energy
- Electron cooling should operate to 4.6 GeV/n (2.5 MeV)
- Transverse polarization does not require solenoids in collider
- Thus, an operation with deuterons will not require large changes in the collider



# Longitudinal Polarization For Protons & Deuterons

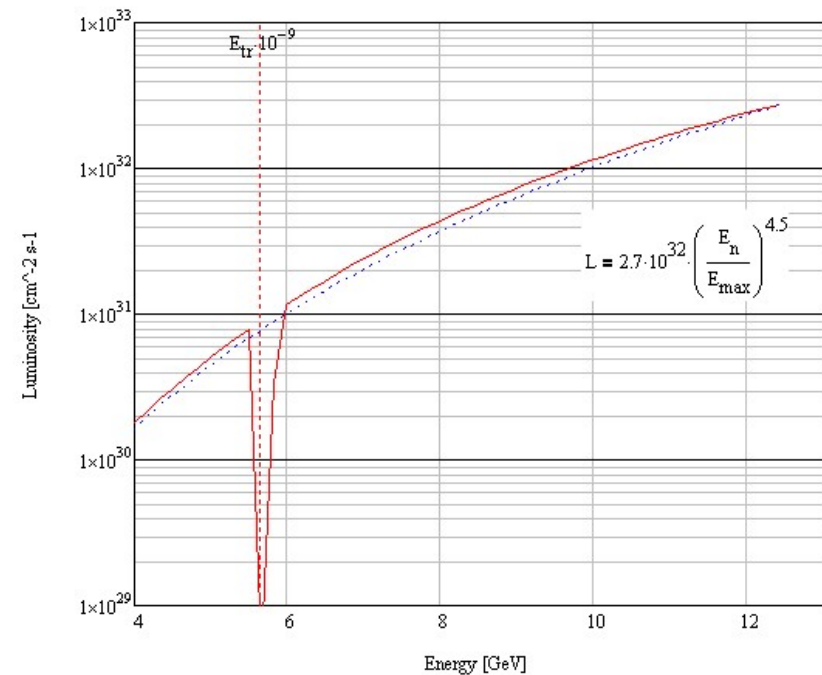
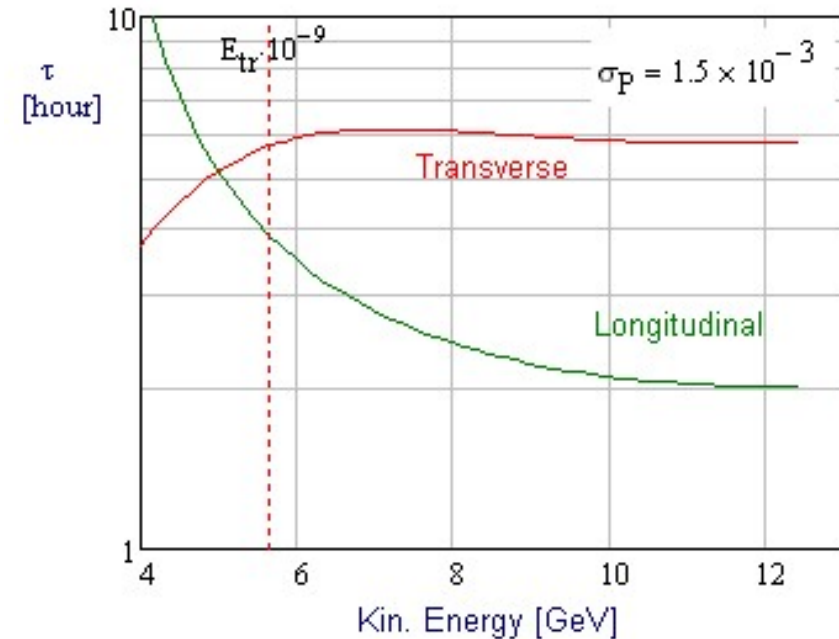
- Longitudinal polarization in the IP can be supported at the integer spin-resonances
  - ◆ For protons:  $E_{kin}=(0.108+0.523 \cdot n)$  [GeV]
  - ◆ For deuterons:  $E_{kin}=(5.62+6.56 \cdot n)$  [GeV/u] or **5.62 GeV/u** in acceptable energy range
- Since for protons the integer resonances happen sufficiently frequently, we can have longitudinal polarization without snakes
- For deuterons we have only one energy available for longitudinal polarization
- An installation of  $180^\circ$  solenoidal snake (50 T m) enables to have the longitudinal polarization for protons in the entire range of operating energy
- Solenoidal snake for deuterons requires too large magnetic field and does not look practical



Field integral required for  $180^\circ$  solenoidal “snake”

# Operation with Protons

- The transition needs to be crossed for protons with  $E > 5.6$  GeV.
  - ◆ It is unfeasible for planned beam intensity due to microwave instabil.
    - Range of  $E_{\text{trans}}$  variation can be increased by separate powering families of F&D quads in arcs but it will negatively affect chromaticity correction & dyn. apert.
- Transition crossing is not a problem for small intensity
  - ⇒ Can and should be done in Nuclotron
  - ⇒ We need electron cooling above transition
    - ◆ 11 GeV cooler is still feasible but will require time and money
      - Fermilab demonstrated operational cooler for 8 GeV antiprotons



## **Choices We Need to Do for SPD**

- Do we need longitudinal polarization
- Do we need the ultimate (top) luminosity for protons
  - ◆ If yes, we need new cooler
  - ◆ We still need to understand how large luminosity we can achieve but it is already known it will be much less than with a top energy or above transition electron cooling

## **Conclusions**

- Heavy ion program is the highest priority for now
  - Making physics with slow extracted polarized deuterons and protons is in plans
  - This workshop has to help us to formulate priorities and build a credible plan
  
  - Getting NICA to success represents great challenge
  
  - Keeping the pace in this turbulent world certainly will not be an easy task
- ⇒ We should do the best to avoid incorrect steps

**“7 раз отмерь” and do it right**