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Секция "Ускорители заряженных частиц и радиационные технологи"

Проектирование Каналов ByPass в Ускорительном Комплексе NICA для Экспериментов с Поляризованными Пучками по Поиску ЭДМ.

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EDM Search: «Frozen Spin»

T-BMT Equations

$$\frac{d\vec{S}}{dt} = \vec{S}\times\left(\vec{\Omega}_{MDM} + \vec{\Omega}_{EDM}\right),$$

$$\vec{\Omega}_{MDM} = \frac{q}{m\gamma}\left\{(\gamma G + 1)\vec{B}_{\perp} + (G+1)\vec{B}_{\parallel} - \left(\gamma G + \frac{\gamma}{\gamma+1}\right)\frac{\vec{\beta}\times\vec{E}}{c}\right\},$$

$$\vec{\Omega}_{EDM} = \frac{q\eta}{2m}\left(\vec{\beta}\times\vec{B} + \frac{\vec{E}}{c}\right), G = \frac{g-2}{2},$$

$$d = \eta\frac{q}{2mc}s$$

MDM term

both
electric & magnetic field

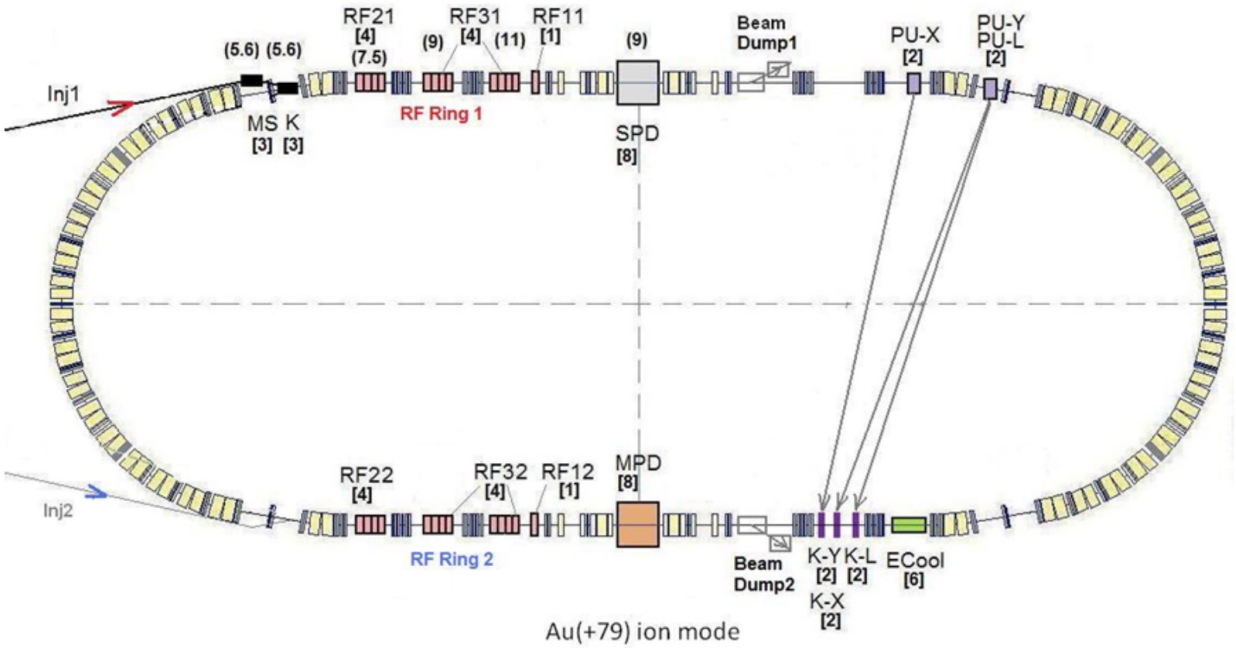
Spin retains its orientation during the <u>entire</u> time of rotation in the ring

EDM Search: «Quasi-Frozen Spin»

Momentum particle rotation	$\Phi_{arc}^{B} = \pi$
Spin Rotation in arc by magnetic field B	$\Phi_{S}^{arc} = \gamma G \cdot \Phi_{arc}^{B}$
Spin Rotation in Wien Filter by E, B field	$\Phi_{S}^{E} = -\left(\gamma G + \frac{\gamma}{\gamma+1}\right)\beta^2 \cdot \Phi_{SS}^{E}$
	$\Phi_{S}^{B} = (\gamma G + 1) \cdot \Phi_{SS}^{B}$
zero Lorentz factor	$\Phi_{SS}^{E} = \Phi_{SS}^{B}$
«QFS» condition	$\Phi_{S}^{B} + \Phi_{S}^{E} = \Phi_{S}^{arc}$

Spin <u>does not</u> retain orientation throughout the entire period of circulation
BUT restores orientation on a straight section

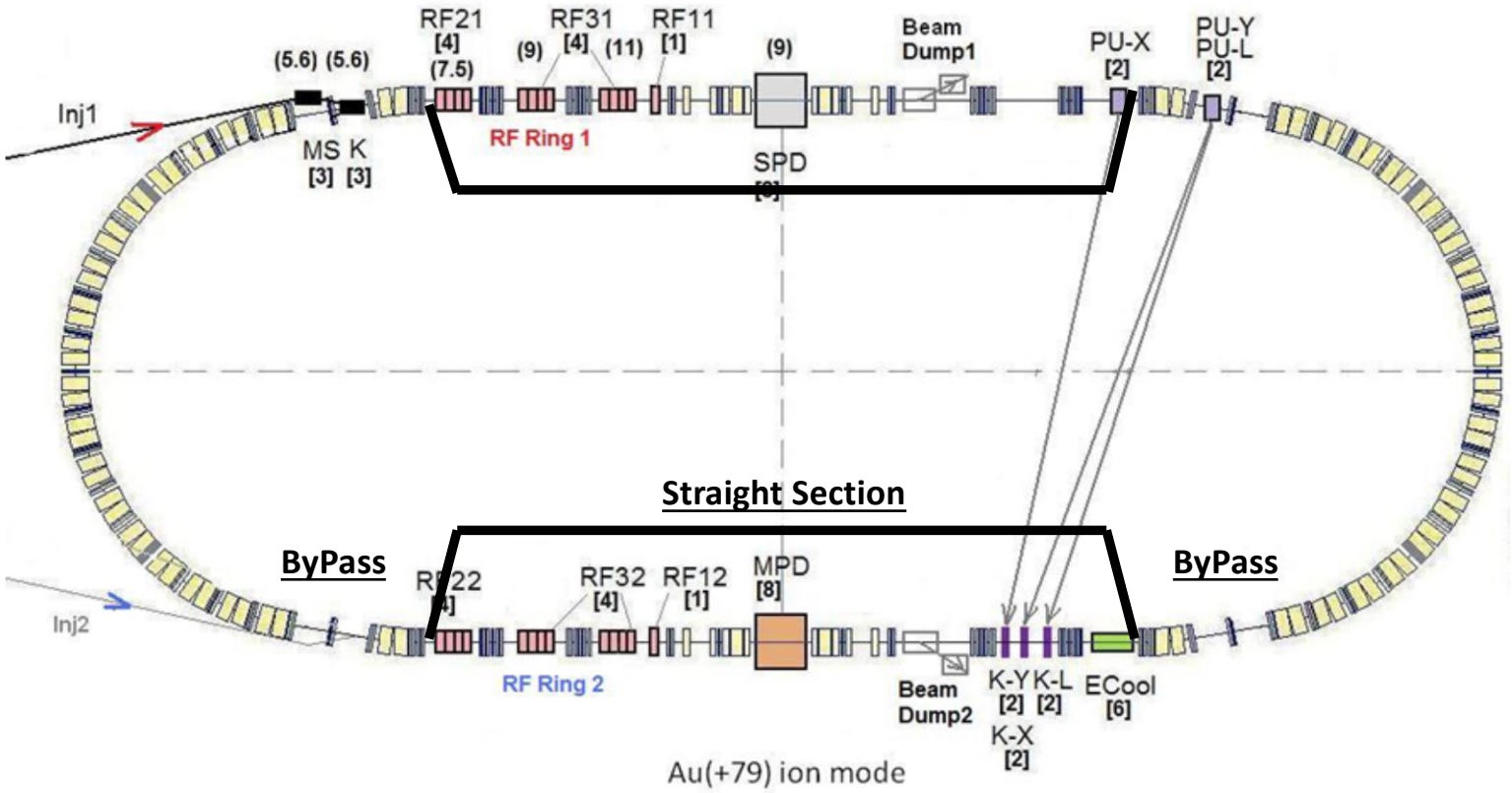
Optics Modernization



Ion mode of NICA

1. Initial Straight Section contains MPD and SPD detectors and other
2. Storage Ring mode to get $T_{SC} \sim 1000$ s

Optics Modernization



Experiment parameters

Energy of experiment

- «Magic» energy only for electrostatic machines.

  NICA has magnetic arcs!
- Particles magnetic moment anomaly

  deutron $G_d = -0.1429$, proton $G_p = 1.7928$

  $\pi \cdot \gamma G_d/2 \sim 0.25$ at 240 MeV ($\gamma = 1.129$)
- The largest scattering cross-section at 270 MeV

Gold

$A_g := 197$

$Z_g := 79$

$W_g := 4500 \ \frac{MeV}{u}$

$E_{kin.g} := W_g \cdot \frac{A_g}{Z_g} = 1.122 \times 10^4$

$\gamma_g := \frac{(m + W_g)}{m} = 5.831$

$\beta_g := \sqrt{1 - \frac{1}{\gamma_g^2}} = 0.985$

$p_{0g} := m \cdot \beta_g \cdot \gamma_g = 5.351 \times 10^3 \ \frac{MeV}{u}$

$E_g := \sqrt{\left(m \cdot \frac{A_g}{Z_g}\right)^2 + W_g^2} = 5.064 \times 10^3$

$Br_g := \frac{A_g}{Z_g} \cdot \frac{p_{0g}}{c} \cdot 10^6 = 44.479$

$B_{dip.g} := \frac{2\pi \cdot Br_g}{L_{dip} \cdot N_{dip}} = 1.801$

Deutrons

$A_d := 2$

$Z_d := 1$

$W_d := 120 \ \frac{MeV}{u}$

$E_{kin.d} := W_d \cdot \frac{A_d}{Z_d} = 240$

$\gamma_d := \frac{(m + W_d)}{m} = 1.129$

$\beta_d := \sqrt{1 - \frac{1}{\gamma_d^2}} = 0.464$

$p_{0d} := m \cdot \beta_d \cdot \gamma_d = 487.809 \ \frac{MeV}{u}$

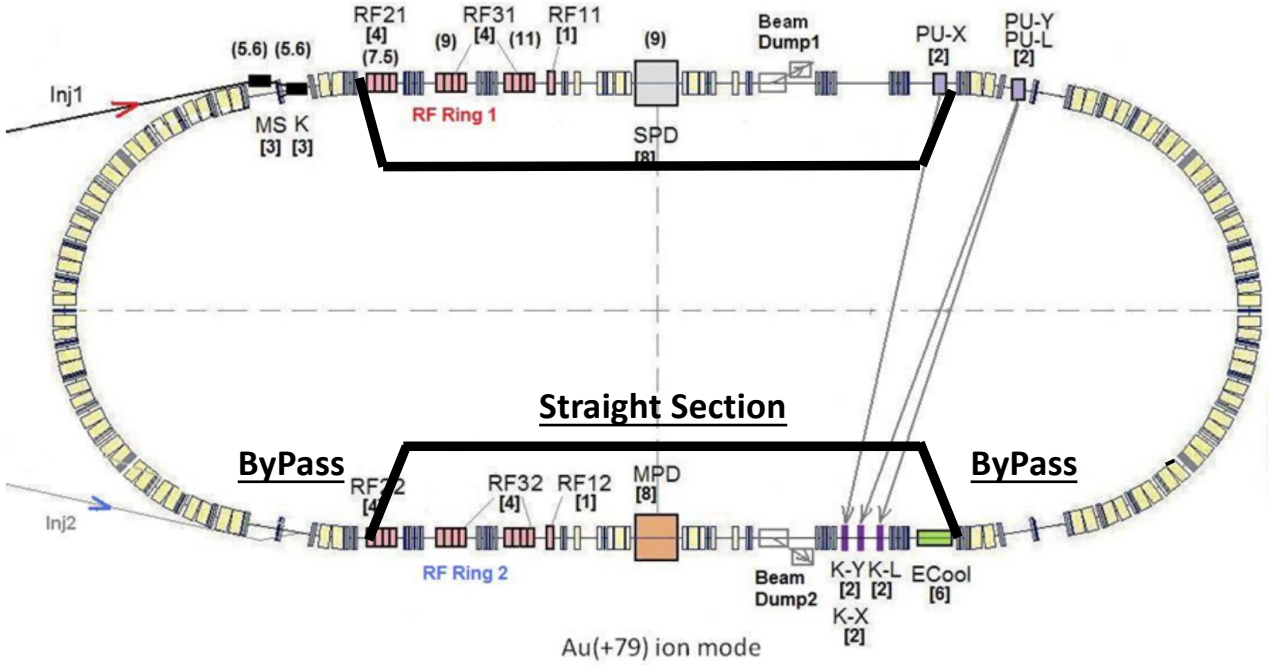
$E_d := \sqrt{\left(m \cdot \frac{A_d}{Z_d}\right)^2 + W_d^2} = 1.867 \times 10^3$

$Br_d := \frac{A_d}{Z_d} \cdot \frac{p_{0d}}{c} \cdot 10^6 = 3.252$

$B_{dip.d} := \frac{2\pi \cdot Br_d}{L_{dip} \cdot N_{dip}} = 0.132$

ByPass Optics Design

Geometry of arcs is planned to remain unchanged → **use NICA for various experiments**

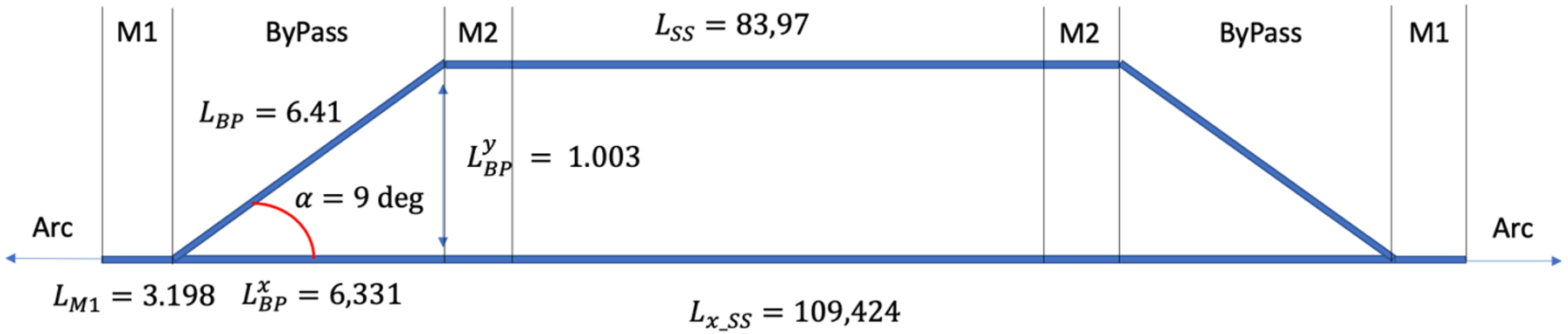


$L_{acc} = 503.04$ m
$L_{arc} = 142.15$ m
$L_{SS} = 109.6$ m

For beam deflection
$\alpha = 9°$
$L_{dip}^{BP} = 50$ cm
$B_{BP} = 1$ T

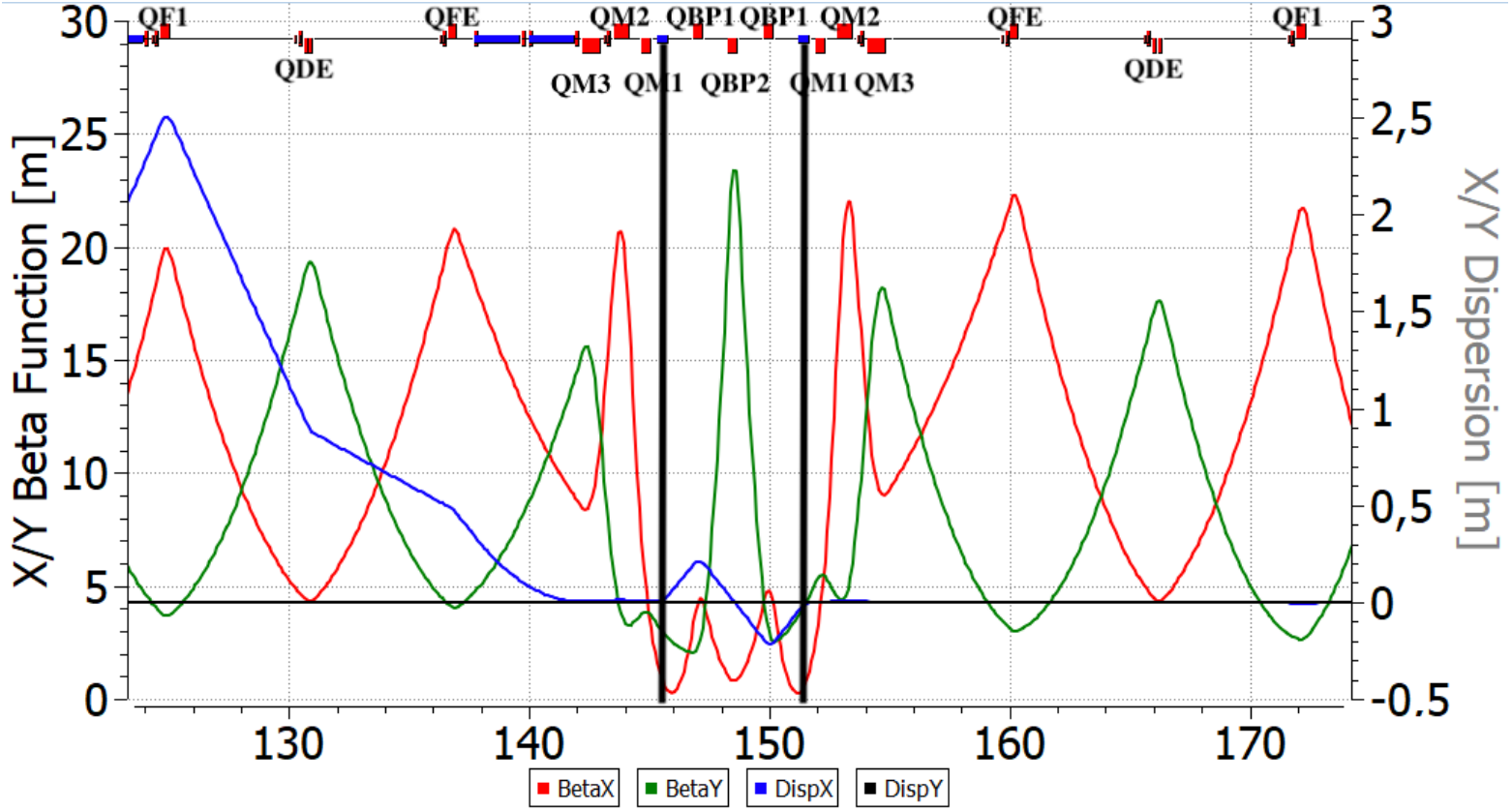
ByPass 3 quadrupoles

Schematic diagram



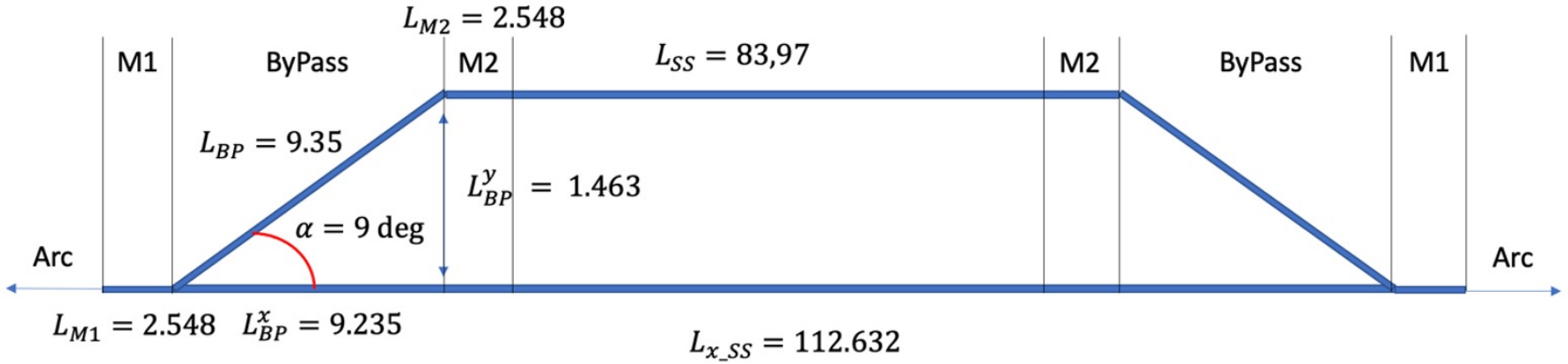
- 3 quadrupoles
- Symmetrical straight section to arc
- Deflection by 1 m in alternative straight section
- M1 and M2 matching sections – identical
- Total length $L_{3quad}^{acc} = 503.46$ m

ByPass 3 quadrupole Twiss-functions



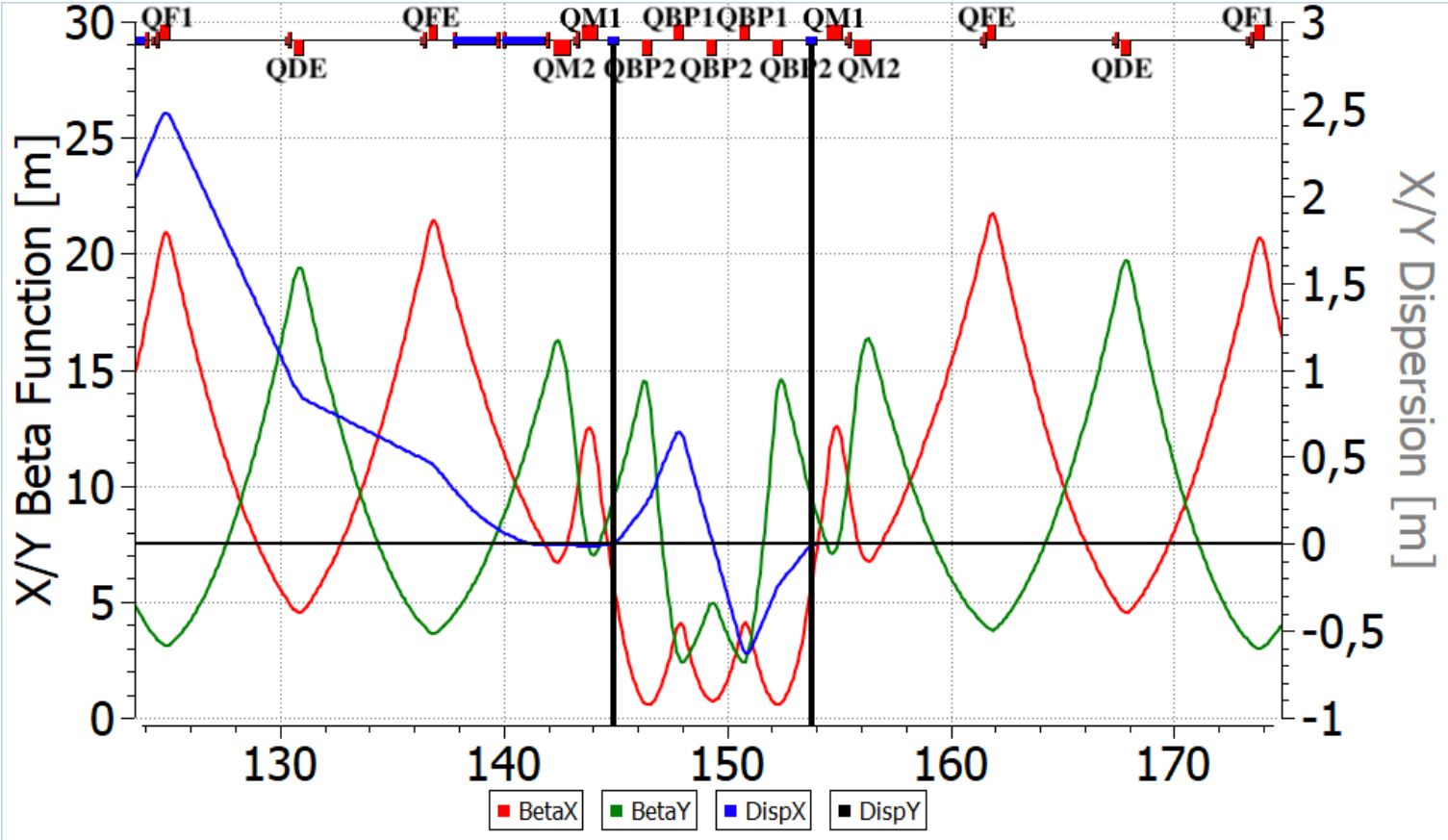
ByPass 5 quadrupoles

Schematic diagram



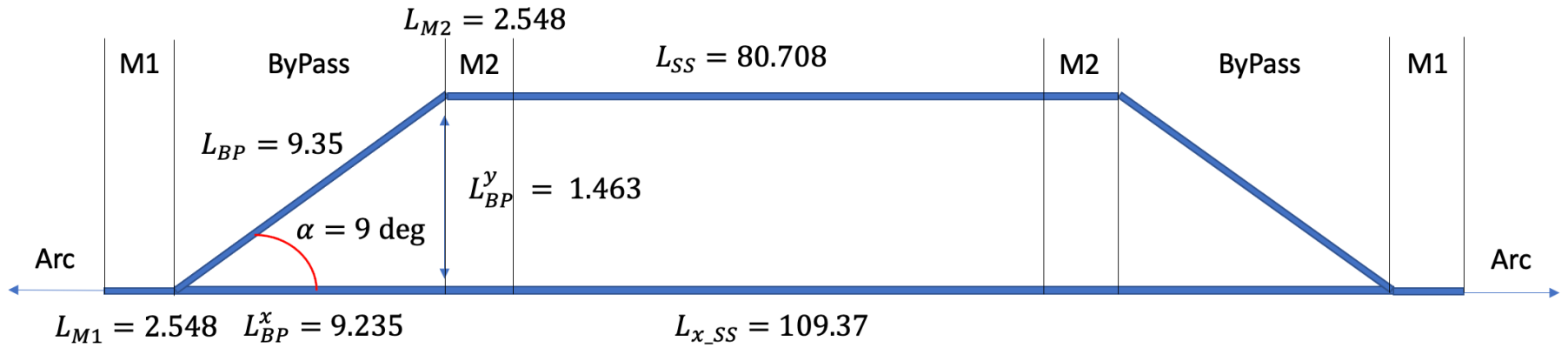
- 5 quadrupoles
- Symmetrical straight section to arc
- Deflection by 1.46 m in alternative straight section
- M1 and M2 matching sections – identical
- Total length $L_{5quad}^{acc} = 510.02$ m

ByPass 5 quadrupoles Twiss-functions



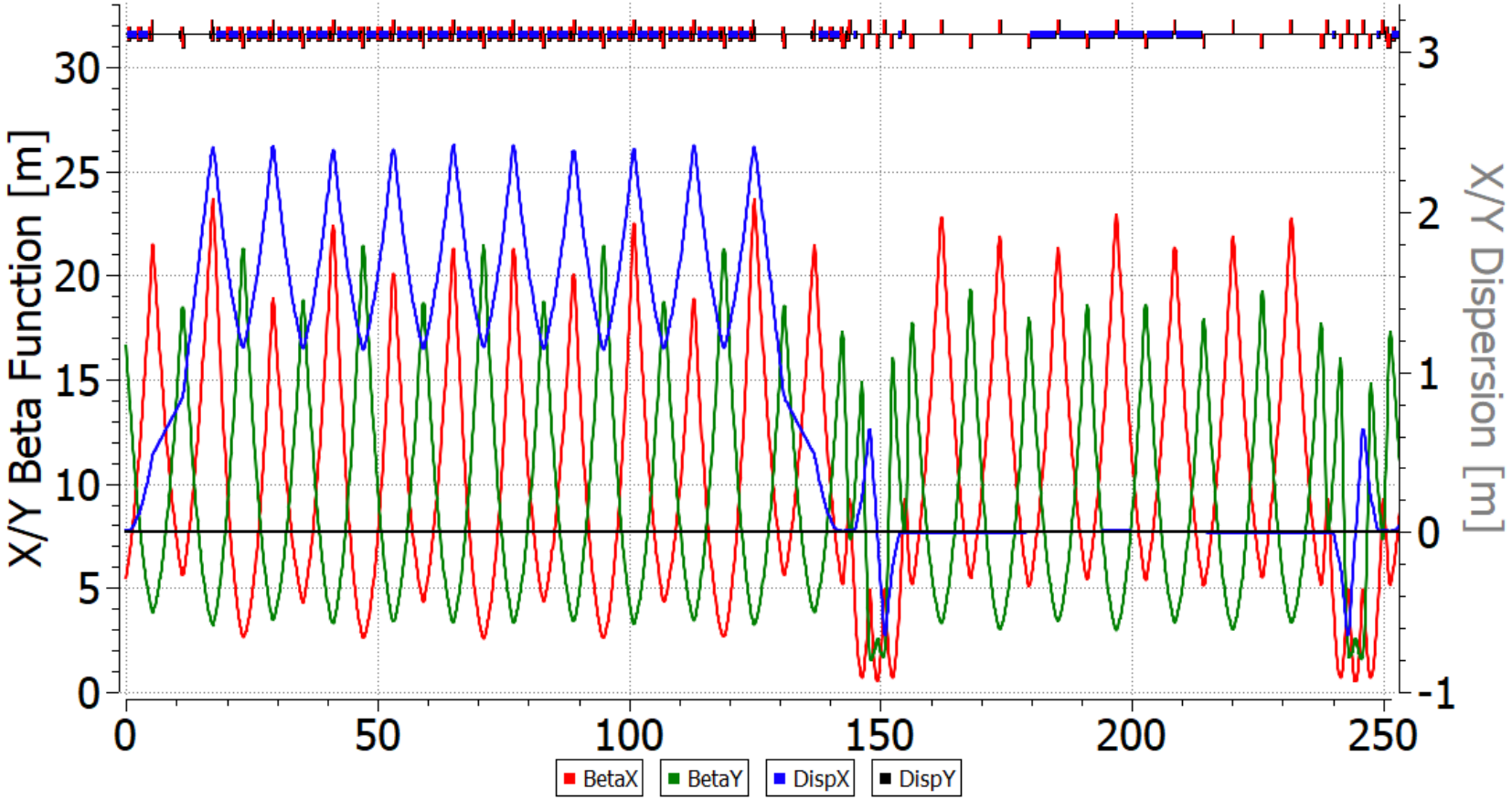
ByPass REAL

Schematic diagram



- 5 quadrupoles
- Regular straight section
- Deflection by 1.46 m in alternative straight section
- M1 and M2 matching sections – different
- Total length $L_{real}^{acc} = 503.5$ m

ByPass REAL Twiss

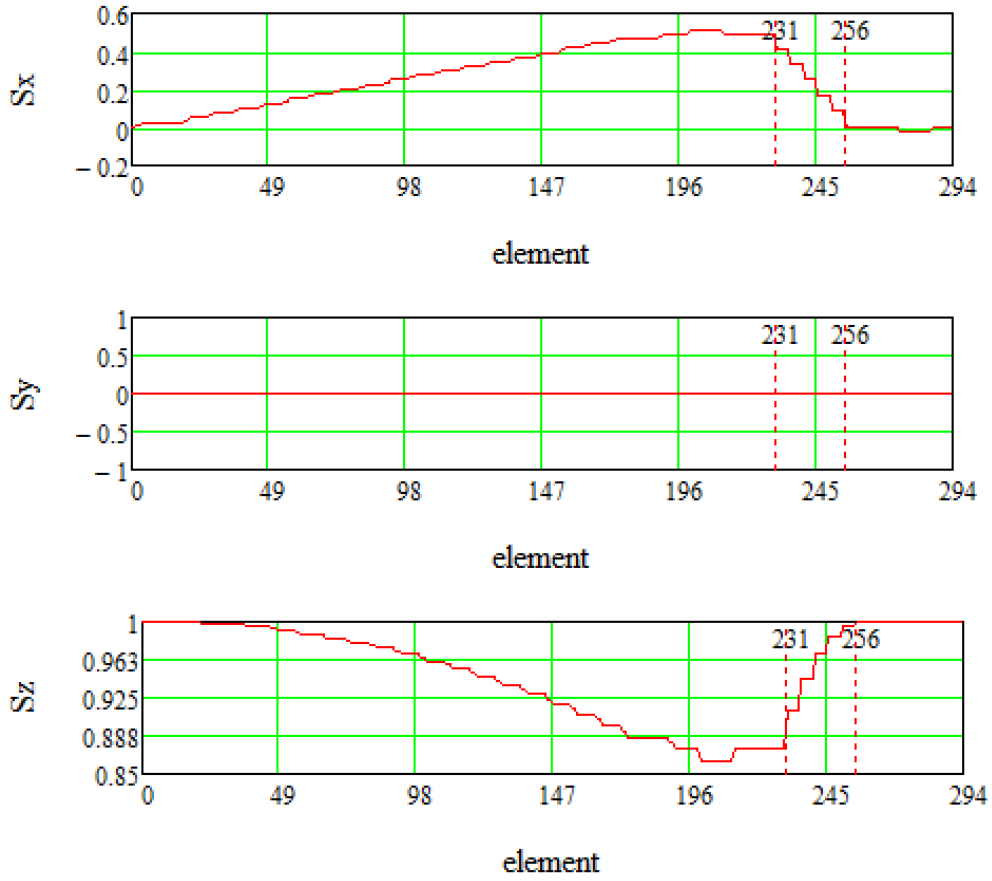


SPIN TRACKING

Spin Tracking in 1/2 of ByPass NICA Storage Ring

Vertically polarized particle

$\overrightarrow{S_0} \sim (0, 0, 1)$



CONCLUSIONS

- Use NICA as a Storage Ring for EDM experiments.
- Considered modernization by creation of an alternative straight sections parallel to the native ones by using ByPass channels.
- Special elements – Wien Filters at straight section to compensate spin rotation in the arcs.
- Considered 2 principals schemes of ByPass channel.
- Got the most realistic case, where straight section is fully regular.
- As arcs remain unchanged, this allows to use NICA in various experiments.
- Spin Tracking simulations shows that ByPass NICA restore spin orientation.