Spin physics at storage rings: from JEDI @ COSY to NICA @ JINR to eIC & BNL and outlook into distant future

(Subtitle: MPD & SPD are two pillars of NICA)

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For the SpinTra collaboration and beyond

SPD@NICA: worldwide leader in pp, pd and dd collider spin physics and polarized beams < 10-20 GeV for decades to come

Principal physics goal: gluon helicity in protons and deuterons as an window at the spin crisis in QCD

Extra options not to overlook: fundamental symmetries in the as yet unexplored domain

- Spin physics at NICA hinges on the proton and deuteron spin gymnastics: expertimental test of the Spin Transparency approach is imperative (Y. Filatov et al.)
- Electric dipole moments of protons & deuterons as an window at CP-violation beyond the Standard Model (BSM) and a mistery of baryogenesis in Universe→ augmentation of NICA by bypass for EDM studies (Y. Senichev et al.)
- T-violation in double polarized pd scatterins as an window at CP-violation BSM
- Parity violation in polarized proton and deuteron interactions
- NICA as an antenna for the QCD axions as a candidate for dark matter

Fundamental point: keeping desired spin orientation is crucial to accomplish the goals of SPD@NICA

- Spin crisis: longitudinal polarization of protons and deuterons is imperative
- Protons: Siberian snakes in principle do the job
- Deuterons: small magnetic anomaly → impractically large field integrals in snakes
- New idea: spin transparency (SpinTra) without snakes by means of spin navigators at integer spin resonances: Yu. N. Filatov, A. M. Kondratenko, M. A. Kondratenko, V. V. Vorobyov, S. V. Vinogradov, E. D. Tsyplakov, A. D. Kovalenko, A. V. Butenko, Ya. S. Derbenev, and V. S. Morozov, Phys. Rev. Accel. Beams **24**, 061001 (2021) and refs. therein
- SpinTra: RSF grant 22-42-04419 (2022-2024): Yu. N. Filatov, A. Kondatenko , Yu.Senichev et. al. (MIPT – JINR – INR RAS – Landau ITP RAS)
- SpinTra: enthusiastic support at COSY, figures as #1 in
- R. Gebel, V. Hejny, A. Kacharava, A. Lechrach, P. Lenisa, A.Nass, J. Pretz, F. Rathmann, H. Ströher, I. Keshelashvili, E. Stephenson, A. Wronska, Y. Filatov, A. Kondratenko, M. Kondratenko, N. Nikolaev , A. Melnikov, Y. Senichev, A. Aksentev, A, Butenko, E. Syresin, A. Saleev, V. Shmakova, S.Karanth, B. Breitkreutz, N. Shurkhno, R. Stassen, A. Pesce, Spin Physics at COSY (2021-2024 and beyond) -- Pathfinder investigations toward an EDM storage ring and Spin-for-FAIR. arXiv:2108.13933

EDM: JEDI Collaboration studies at COSY in Juelich, culminating in the proposal of the prototype all electric (and hybrid) storage ring PTR and perspectives at NICA

Storage ring to search for electric dipole moments of charged particle. Feasibility study (CPEDM Collaboration): … A. Aksentev,.. , S. Dymov, …, I. Koop,…, N. Nikolaev, …, V. Shmakova, …, A. Silenko, Y. Senichev,…, Y. Uzikov,… CERN Yellow Reports: Monographs, CERN-2021-003, 246 pp., arXiv 1912.07881

- An integral part of broad discussions of Physics Beyond the Standard Model in the post-LHC era
- PTR: first ever all electric storage ring : unfrozen spin protons, 30 MeV
- Hybrid PTR, electric + magnetic ring: first frozen spin protons, 45 MeV
- From the ring to racetrack? (Y. Senichev and collaborators)
- Ultimate goal: all electric 500 m proton EDM storage ring with spins frozen at 233 MeV (with 10^{-29} e cm sensitivity)
- Alternative proposal by srEDM (BNL & IBS, Daewon, S. Korea, et al) to go straight to the ultimate EDM ring skipping the PTR systematics study stage: Zh. Omarov, …, V. Lebedev, W. Morse, Y. Semetrzidis, A. Silenko, E. Stephenson, R. Suleiman, A proposal to measure the proton electric dipole moment with 10^{-29} e cm sensitivity, e-Print: 2007.10332

New paradigm of oscillating (in-plane precessing) beam polarization at NICA

Physics Case #1 T-violation at NICA as a search for CP-violation beyond the Standard Model

N.N. Nikolaev, F. Rathmann, A.J. Silenko, Yu. Uzikov, *New approach to search for parity-even and parity-odd time-reversal violation beyond the Standard Model in a storage ring*, Physics Letters B 811, 135983 (2020);

Physics Case #2 Parity violation at NICA as a test of the Standard Model (RFBR 18-02-40092 Mega)

No conclusive experimental data at intermediate and high energies so far

I.A. Koop, A.I. Milstein, N.N. Nikolaev, A.S. Popov, S.G. Salnikov, P.Yu. Shatunov, Yu.M.Shatunov, *Strategies for Probing P-Parity Violation in Nuclear Collisions at the NICA Accelerator Facility*, Physics of Particles and Nuclei Letters, 17(2), 154-159 (2020)

I.A. Koop, A.I. Milstein, N.N. Nikolaev, A.S. Popov, S.G. Salnikov, P.Yu. Shatunov, Yu.M. Shatunov, *Tests of Fundamental Discrete Symmetries at the NICA Facility: Addendum to the Spin Physics Programme*, Physics of Particles and Nuclei, 52(4), 549-554 (2021); Physics of Particles and Nuclei, 52(6), 1044-1119 (2021)

Physics case # 3: NICA as an axion antenna

- A.Silenko, Relativistic spin dynamics conditioned by dark matter axions, e-Print: 2109.05576 [hep-th]
- S. Vergeles, N. Nikolaev, Yu. Obukhov, A. Silenko, O.Teryaev, to be published in Phys. Uspekhi, DOI: 10.3367/UFNe.2021.09.039074, arXiv 2204.00427
- N. Nikolaev, Spin of protons in NICA and PTR storage rings as an axion antenna, accepted in JETP Letters
- Dozens of expts worldwide on search for the QCD axions as a dark matter candidate
- The observable signal: spontaneous emergence of precessing horizontal polarization when you hit the spin resonance with oscaillating Galatic axion field

Physics case # 4: PTR (CPEDM Collaboration) and Quasi-Frozen Spin approach to EDM at NICA furnished with bypass (Y. Senichev and collaborators)

Physics case # 5: SpinTra test experiment at Nuclotron

Highlights of JEDI @ COSY

JEDI-2015 (PRL 115 (2015) 094801) : the Fourier analysis makes the in-plane precessing spin as good as the static one

JEDI technique: put the polarization in the ring plane and monitor oscillating radial P_x by time-stamped up-down asymmetry in the polarimeter
Longitudinal polarization is known as soon as the radial one and the spin precession phase have been measured !

Forerunners:

- I.B.Vasserman et al., Phys. Lett. B 187 (1987) 172 (High precision comparison of (g-2) in e+e- by comparison of the concurrent in-plane precession of e+ & e- spins at Budker INP)
- I.M. Sitnik et al., PEPAN Letters No. 2 [111] (2002) (Suggestion to accelerate the in-plane polarized deuterons in Nuclotron)

EDM as window at Baryiogenesis: P- and T-violating spin rotation in the electric field

- CP-violation is imperative for baryogenesis (A.D. Sakharov)
- Ring frequency ~ 0.5 MHz
- Spin precession (deuterons) ~ 0.1 MHz
- RF (solenoid, straight section Wien filter) driven parametric spin resonance at precession frequency: up-down spin rotation ~ 1 Hz
- Target for the pEDM signal in all electric frozen-spin ring ~ 1 nHz for pEDM ~ 10^{-29} e cm.
- Continuous spin rotation for ~ 1000 s for a visible spin rotation angle
- A commensurate and longer spin coherence time
- Elimination of the background from magnetic moment rotation
- Large background from the Earth gravity pull

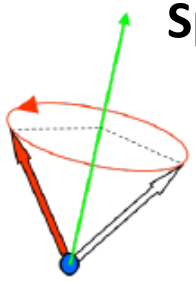
Spin coherence

Most polarization experiments don't care about coherence of spins along $\vec{n}_s$

Spins aligned:

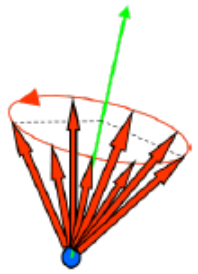
Ensemble *coherent*

Spin stable axis n_s



Spins out of phase:

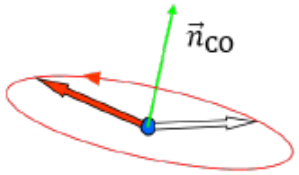
Ensemble *decoherent*



$\Rightarrow$ **Polarization components along $\vec{n}_s$ not affected**

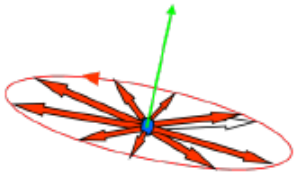
With in-plane spins: $\vec{S} \perp \vec{n}_s$:

Ensemble *coherent*



Over time:

Spins out of phase in horizontal plane



$\Rightarrow$ **In-plane polarization vanishes**

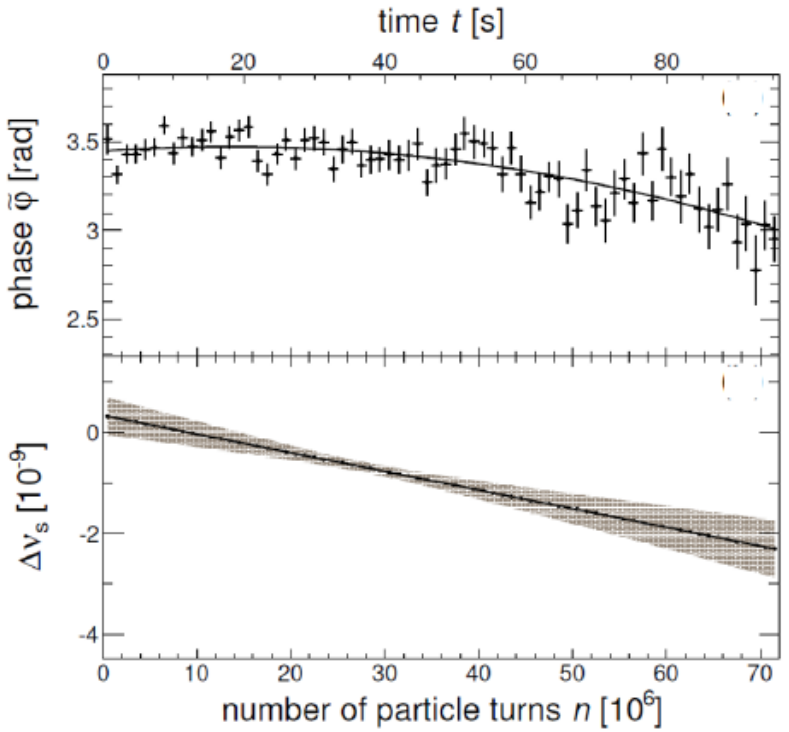
Determination of spin tune [15]

$\theta_s = 2\pi\nu_s$ is spin precession angle per turn,
$\nu_s = G\gamma$ is the spin tune

Analyze all time intervals:

- Monitor phase of measured asymmetry with assumed fixed spin tune ν_s^{fix} in a 100 s cycle:

$$\nu_s(n) = \nu_s^{\text{fix}} + \frac{1}{2\pi}\frac{\mathrm{d}\tilde{\phi}}{\mathrm{d}n} \qquad (6)$$
$$= \nu_s^{\text{fix}} + \Delta\nu_s(n)$$



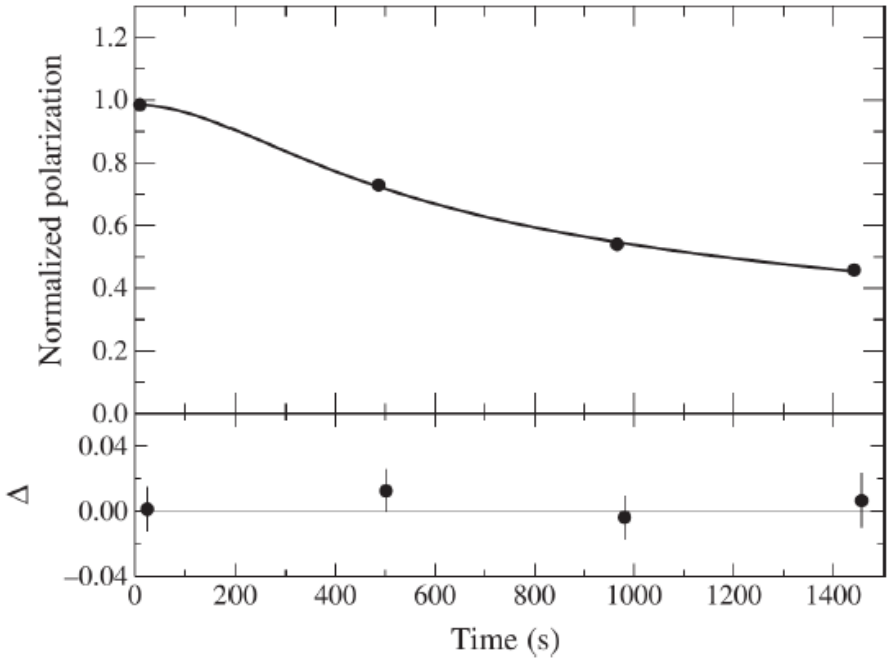
Experimental technique allows for:

- Spin tune ν_s determined to $\approx 10^{-8}$ in 2 s time interval.
- In a 100 s cycle at $t \approx 38$ s, interpolated spin tune amounts to $|\nu_s| = (16097540628.3 \pm 9.7) \times 10^{-11}$, *i.e.*, $\Delta\nu_s/\nu_s \approx 10^{-10}$.

$\Rightarrow$ **New precision tool to study systematic effects in a storage ring.**

Koop-Shatunov technique of tuning the chromaticity

Optimization of spin-coherence time [17]



JEDI progress on τ_{SCT}:

$$\tau_{SCT} = (\mathbf{782 \pm 117})\,\mathrm{s}$$

- Previous record:
  $\tau_{SCT}(\mathrm{VEPP}) \approx 0.5\,\mathrm{s}$ [16]
  ($\approx 10^7$ spin revolutions).

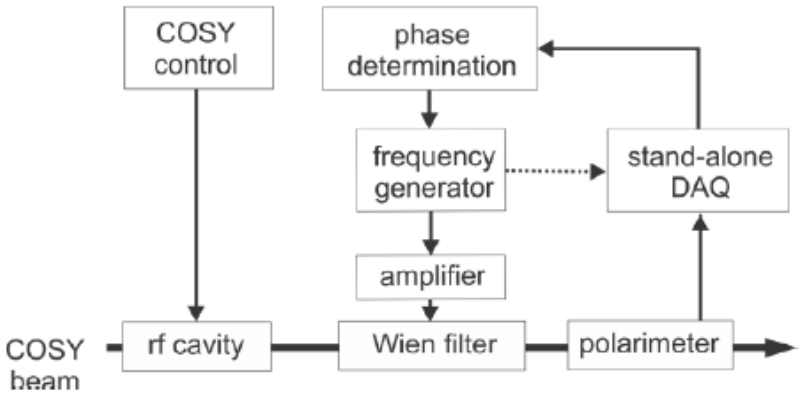
In 2015, way beyond expectation:

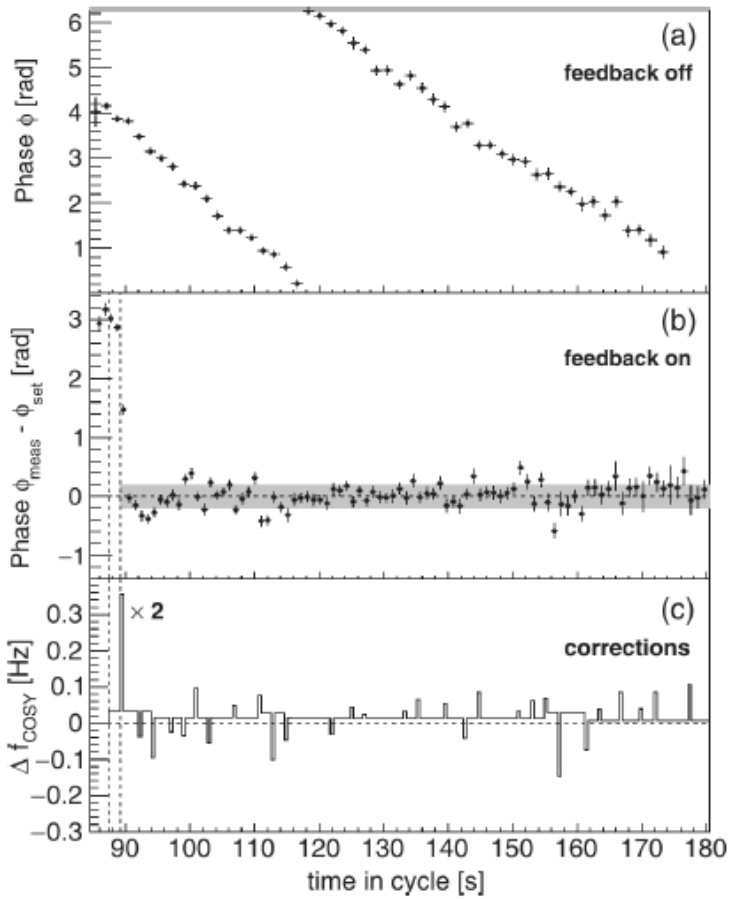
- With about 10^9 stored deuterons.
- Spin decoherence considered one main obstacle of srEDM experiments.

Phase locking spin precession in machine to device RF

Feedback system maintains

1. resonance frequency, and
2. phase between spin precession and device RF (solenoid or Wien filter)





Major achievement : Error of phase-lock $\sigma_\phi = 0.21\,\text{rad}$ [18].

Physics case #1: millistrong T- and CP-Violation beyond SM

1965: L.Okun; J.Prentki & M.Veltman; T.D.Lee & L.Wolfenstein :

T-violating, P-conserving and flavor conserving millistrong TVPC interactions as a source of CP violation in kaon decays.

Utterly beyond SM predictions: ~ 10^{-3} T-violation in

EDM of nucleons: $d \sim 10^{-3} \times 10^{-7}\ \mu_N \sim 10^{-24}$ e cm

β-decays, nuclear γ-transitions, breaking of detailed balance in nuclear reactions,

T-violating spin correlations in double polarized interaction :

n(vector) ^{165}Ho (tensor) $A_{TVPC} < 1.2 \times 10^{-5}$ Huffman et al. PRC 55 (1997) 2684

Can't be induced by initial and final state interactions without explicit T-violation (Y.Uzikov et al.)

Intriguing possibility to resolve the baryogenesis puzzle ? (as yet hardly explored by theorists --- does not occur maturally in renormalizable modles)

Decomposition of the pd total X-section (k = collision axis)

$$\sigma_{\rm tot} = \sigma_0 + \sigma_{\rm TT}\left[\left(\mathbf{P}^{\rm d}\cdot\mathbf{P}^{\rm p}\right) - \left(\mathbf{P}^{\rm d}\cdot\mathbf{k}\right)\left(\mathbf{P}^{\rm p}\cdot\mathbf{k}\right)\right]$$

PC TT

$$+\,\sigma_{\rm LL}\left(\mathbf{P}^{\rm d}\cdot\mathbf{k}\right)\left(\mathbf{P}^{\rm p}\cdot\mathbf{k}\right) + \sigma_{\rm T} T_{mn}k_m k_n$$

PC LL & PC tensor

$$+\,\sigma^{\rm p}_{\rm PV}\left(\mathbf{P}^{\rm p}\cdot\mathbf{k}\right) + \sigma^{\rm d}_{\rm PV}\left(\mathbf{P}^{\rm d}\cdot\mathbf{k}\right)$$

PV single spin

$$+\,\sigma^{\rm T}_{\rm PV}\left(\mathbf{P}^{\rm p}\cdot\mathbf{k}\right) T_{mn}k_m k_n$$

PV tensor

$$+\,\sigma_{\rm TVPV}\left(\mathbf{k}\cdot\left[\mathbf{P}^{\rm d}\times\mathbf{P}^{\rm p}\right]\right)$$

TVPV

TVPC $+\,\sigma_{\rm TVPC} k_m T_{mn}\epsilon_{nlr}P^{\rm p}_l k_r\,.$

(TRIC Proposal in Juelich)

$$k_m T_{mn}\epsilon_{nlr}P^{\rm p}_l k_r = T_{xz}P^{\rm p}_y - T_{yz}P^{\rm p}_x$$

Deuterons in a ring with resonance RF solenoid or Wien Filter as a spin flipper

n = turn number

Precession angle per turn

$$\theta_s = 2\pi\nu_s$$

Spin resonance tune vs. spin kick per turn $\nu_{res} = \frac{\epsilon}{2\pi}$ $\epsilon = \frac{1}{2}\psi_{RF}$

in-plane idle precession

$$\vec{S}(n) = S_y(0)[\vec{e}_y \cos \epsilon n + \sin \epsilon n(\vec{e}_x \cos \theta_s n - \vec{e}_z \sin \theta_s n)]$$

vertical radial **PV** longitudinal

cos ε n, sin ε n -- the envelopes of polarization. Freezing point $\epsilon n = \frac{\pi}{2}$

Deuterons: the in-plane spin idle precession at about 90 kHz

$$\langle S_{x,z}(0)\rangle = 0 \quad \rightarrow \quad \langle Q_{yx}(0)\rangle, \quad \langle Q_{yz}(0)\rangle, \quad \langle Q_{xz}(0)\rangle = 0$$

$$\langle Q_{yy}(n)\rangle = \tfrac{1}{2}\langle Q_{yy}(0)\rangle[-1 + 3\cos^2 \epsilon n]\,,$$

$$\langle Q_{xx}(n)\rangle = \tfrac{1}{2}\langle Q_{yy}(0)\rangle[-1 + 3\sin^2 \epsilon n \cos^2 \theta_s n]\,, \qquad \leftarrow P^P_y \text{ even}$$

$$\langle Q_{zz}(n)\rangle = \tfrac{1}{2}\langle Q_{yy}(0)\rangle[-1 + 3\sin^2 \epsilon n \sin^2 \theta_s n]\,,$$

$$\langle Q_{yx}(n)\rangle = \tfrac{3}{4}\langle Q_{yy}(0)\rangle \sin 2\epsilon n \cos \theta_s n\,, \qquad \leftarrow \text{freezes at } 0$$

$$\langle Q_{yz}(n)\rangle = -\tfrac{3}{4}\langle Q_{yy}(0)\rangle \sin 2\epsilon n \sin \theta_s n\,, \qquad \leftarrow \text{freezes at } 0$$

TVPC → $$\langle Q_{xz}(n)\rangle = -\tfrac{3}{4}\langle Q_{yy}(0)\rangle \sin^2 \epsilon n \sin 2\theta_s n\,, \qquad \leftarrow P^P_y \text{ odd}$$

Uniqely free of systemanic effects

N.N. Nikolaev, F. Rathmann, A.J. Silenko, Yu. Uzikov, *New approach to search for parity-even and parity-odd time-reversal violation beyond the Standard Model in a storage ring*, Physics Letters B 811, 135983 (2020);

Time Reversal Invariance Conservation (TRIC/TIVOLI): proposal for COSY

The conventional method: search for PVPC asymmetry in total X-section with vertical vector polarized protons in the ring and tensor polarized deuterons in the ABS target

Valdau et al. (2016): test stand experiment with Bergoz Fast Current Transformer --- the COSY bunches simulated by pulsed current in the wire

Optimistic conclusion: the cross section asymmetry of 10^{-6} is within the reach of 1 month run with FCT already in the COSY ring.

Requires a suppression of false signal from stray vector polarization of deuterons to < 10^{-6} --- no solution found so far

Precessing polarization: TVPC has a unique signature and is free of the systematic background

Physics case #2: testing SM by Parity Violation (PV)

- The observable: PV beam helicity dependence of the total X-section and elastic scattering
- Unitarity considerations suggest suppression of PV in inelastic X-section → enhancement of PV in elastic scattering vs. total X-section
- A challenge to experimentalists: the expected asymmetries are few 10^{-8} to 10^{-7} --- counting events is entirely hopeless
- I.A. Koop, A.I. Milstein, N.N. Nikolaev, A.S. Popov, S.G. Salnikov, P.Yu. Shatunov, Yu.M. Shatunov, *Tests of Fundamental Discrete Symmetries at the NICA Facility: Addendum to the Spin Physics Programme*, Physics of Particles and Nuclei, 52(4), 549-554 (2021); Physics of Particles and Nuclei, 52(6), 1044-1119 (2021)
- B.G. Zakharov, Sov. J. Nucl. Phys. Sov. J. Nucl. Phys., 42 (3), 479-482 (1985)]

What is the state of art in PV?

Bonn: pp elastic scattering at 45 MeV (SIN (PSI)), several years of running, S. Kystrin et al. PRL 58 (1987) 1616

$A_{PV} = (1.5 +/- 0.22)\ 10^{-7}$

Consistent with expectations from low-energy meson exchange models

ANL ZGS: p(H_20), 5.1 GeV, Nigel Lockyer et al. Phys.Rev. D30 (1084) 860

$A_{PV} = (26.5 +/- 6.0 +/- 3.6\ )\ 10^{-7}$

None of theorists has ever been able to explain this gigantic effect

PV expt with deuterons extracted from Nuclotron (NICA ?)

Very fast (< 1 s) rotation of spin from vertical to the in-plane by RF spin flipper (solenoid)

JEDI: the spin phase for time stamp is measured by internal polarimeter within 1-2 seconds

Time stamp allows single-turn extraction of the bunch with any desired spin orientation:
P_z = +/-1 for PV, P_x=+/-1 for s crosscheck (N. Piskunov: from NICA to the beam dump cave ?)

Beam prep & spin-flip & polarimetry & extraction cycle shorter than 5 s → > 10^5 cycles per month.

No stringent demands for the deuteron beam cooling from the spin coherence time consideration (5 s << 1400 s of JEDI)

A possibility to run PV expt in Nuclotron parasitically while NICA is busy in the collider mode

Modest additions to Nuclotron: RF spin flipper and polarimeter (V.Ladygin et al ? COSY?)

PV expt with deuterons extracted from Nuclotron (new Booster ?) – 2

Measure the total charges of bunches ($>10^{10}$) upstream and downstream the dense target.

Non-invasive measurement of the beam charge by Rogowski coils

Bunched beam: signal from the Rogowski coil = the derivative of the beam current

Two integratons:

1-st integration → current of the bunch

2-nd integration → total charge in the bunch

Upstreasm and downstream families of 3-5 Rogowski coils for crosscheck and boosting the precision

The complementary polarimetry behind the target to monitor the polarization of the beam

PV asymmetries < 10^{-7} are well within the reach at NICA

Physics case # 3 : storage ring as an axion antenna

- Axion search in progress at COSY
- Peccei-Quinn axions as a solution to the strong CP problem
- Galactic axion field acts as an RF spin rotator →

  oscillating EDM of static particles ➔ RF WF

  Weinberg interaction induces pseudomagnetic tangential field acting on the spin of particles orbiting in storage rings ➔ RF solenoid
- Pseudomagnetic field enhanced by the velocity of particles in the ring vs. ~250 km/s velocity of Earth w.r.t. the center of Galaxy

  A. Silenko 2109.05576 [hep-th]
- Pseudomagnetic field is much more important than the oscillating EDM: two orders in magnitude for protons and one order for deuterons

As an axion antenna the vertical spin is superior to the horizontal one:

- The axion spin rotation is entirely independent of the inaccessible phase of the axion field
- No complications with multibunch fills to overcome the phase ambiguity
- No need for a long spin coherence time: allows to extend the technique from deuterons to protons (expected to have very short spin coherence time)
- Just keep scanning the energy and wait and see for the axion resonance at any storage ring with polarimetry
- PTR off frozen spin point will be a broadband axion antennf

Physics case # 4: EDM: P & T –violating rotation of the spin in the electric field

BNL (Yu.F. Orlov et al.): all electric ring for 233 Mev protons, $\nu = 0$.

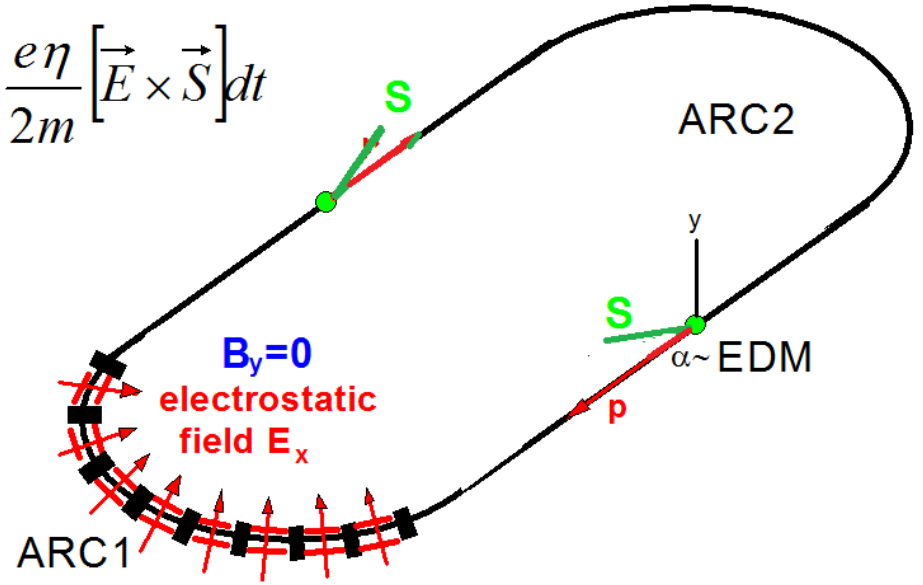
Ultimate sensitivity to $d_p \sim 10^{-29}$ e cm (PSI: $d_n < 10^{-26}$ e cm).

$\Omega_{EDM} = 10^{-9}$ Hz

PTR at 45 MeV: $\nu=0$ for fine tuned B- and E-fields

Eliminate the background from MDM rotation in unwanted magnetic fields

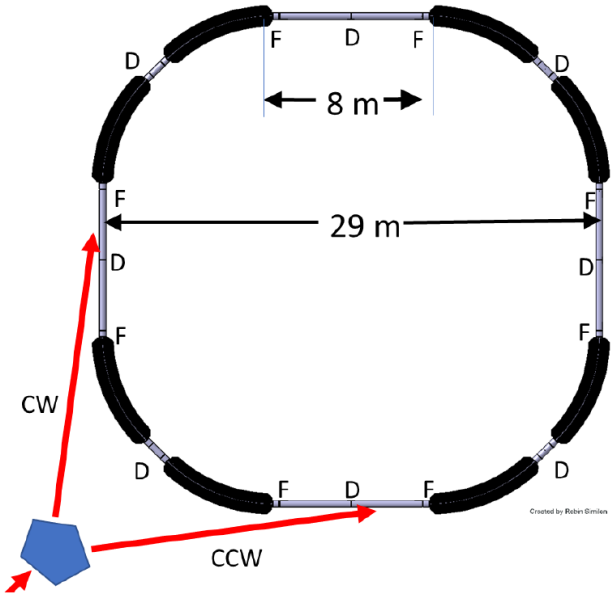
$$d\vec{S} = -\frac{e\eta}{2m}\left[\vec{E}\times\vec{S}\right]dt$$

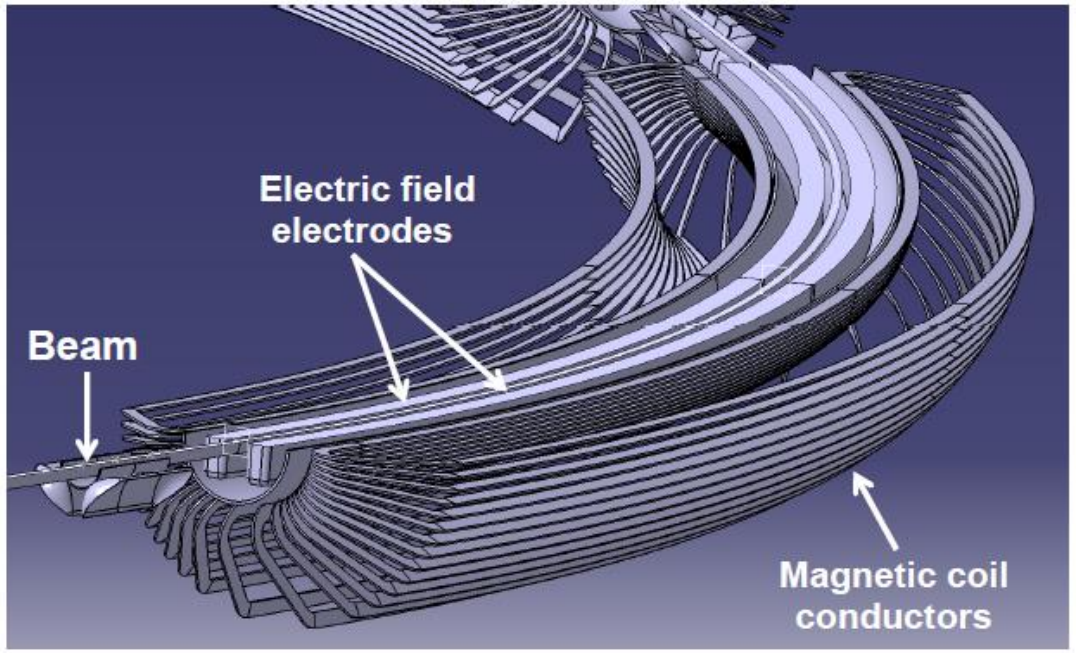


EDM: PTR for protons: all electric bend, concurrent CW and ACW beams, 30 MeV,

frozen spin in hybrid bend, 45 MeV

CPEDM Collab., CERN Yellow Reports: Monographs, CERN-2021-003, 246 pp., arXiv 1912.07881

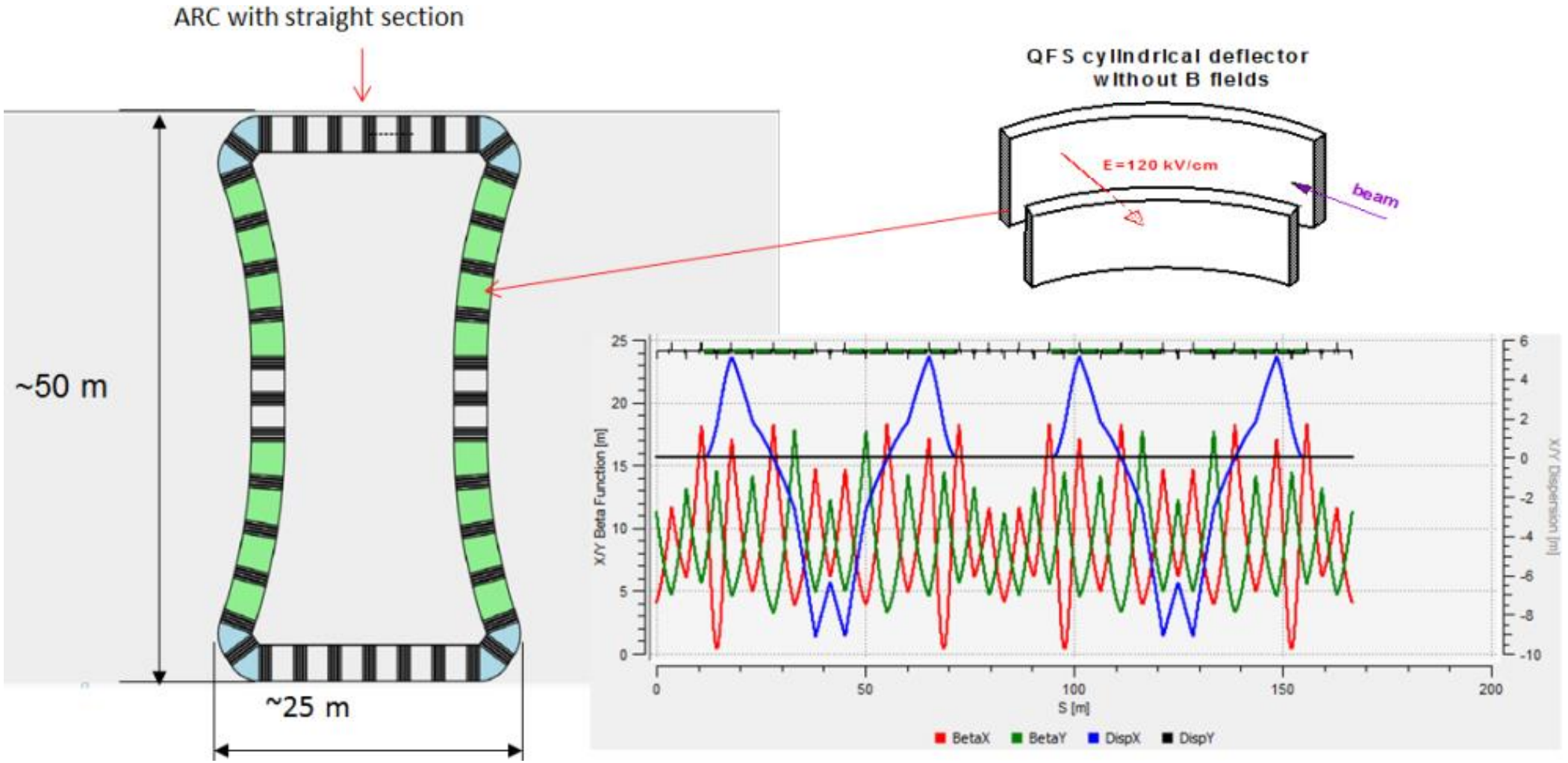




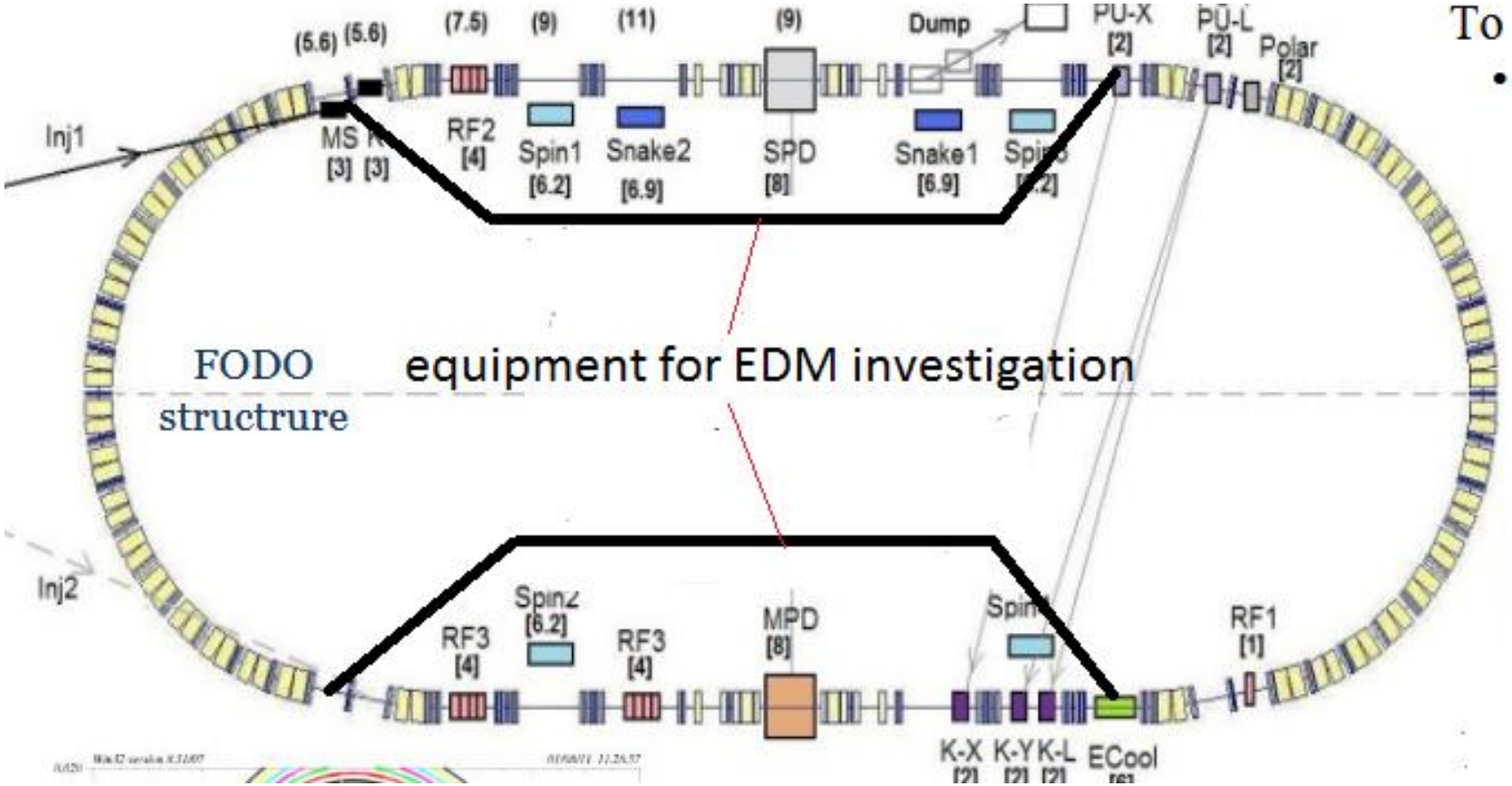
Prototype to ultimate pEDM ring with proton spin frozen along the momentum at the magic energy 233 MeV. CW and ACW beams to cancel systematic effects, e.g., from gravity

Physics case # 4 cont'd: Quasi-frozen spin in a E+B hybrid lattice (separated E and B bends)

(Yu. Senichev, 06/03/2020 JINR seminar, RUPAC 2021)



QFS at NICA (Yu. Senichev et al): bypass with the radial E-field to rotate EDM



Challenge of small $\Omega_{EDM} = 10^{-9}$ Hz → Frequency Domain Method: new paradigm of measuring frequency instead of the amplitide

1. Senichev Y, Aksentev A, Ivanov A and Valetov E., Frequency domain method of the search for the deuteron electric dipole moment in a storage ring with imperfections, preprint arxiv:1711.06512 [physics.acc-ph], 2017

2. A E Aksentev and Y V Senichev, Frequency domain method of the search for the electric dipole moment in a storage ring, J. Phys. Conf. Ser.1435, 012026 (2020), URL https://doi.org/10.1088/1742-6596/1435/1/012047.

$$\Omega = \sqrt{\left(\Omega_{edm} + \Omega_{B_r}\right)^2 + \Omega^2_{\mathrm{B_v},E_r} + \Omega^2_{\mathrm{B_z}}},$$

Ω_x Ω_y Ω_z

Frequency Domain Method: systematic errors

$$\Omega = \sqrt{\left(\Omega_{edm} + \Omega_{B_r}\right)^2 + \Omega^2_{\mathrm{B_v},E_r} + \Omega^2_{\mathrm{B_z}}},$$

We can not realize $\Omega^2_{\mathrm{B_v},E_r},\ \Omega^2_{\mathrm{B_z}} << \Omega^2_{edm}$

but we can have $\Omega^2_{\mathrm{B_v},E_r},\ \Omega^2_{\mathrm{B_z}} << \left(\Omega_{edm} + \Omega_{B_r}\right)^2$

Realizaion of the 2D frozen spin option: $\left(\Omega_{B_r}\right)^2 >> \Omega^2_{\mathrm{B_v},E_r},\ \Omega^2_{\mathrm{B_z}}$

$$\Omega = \left(\Omega_{edm} + \Omega_{B_r}\right)\left[1 + \frac{1}{2}\frac{\Omega^2_{B_v,E_r} + \Omega^2_{B_z}}{\left(\Omega_{edm} + \Omega_{B_r}\right)^2}\right]$$

A principal idea: a suppression of the backround MDM effects from $\Omega^2_{\mathrm{B_v},E_r}, \Omega^2_{\mathrm{B_z}}$ Compared to the EDM signal

A tactics of the Frequency Domain Approach to a search for the EDM

- Measure the sum and difference frequency of spin precession in the vertical plane due to EDM and MDM , for the CW and CCW beams, respectively;
- It suffices to reach an accuracy 10^{-7} rad/s in one fill;
- Absolute accuracy of determinatoion of the spin precession frequency is independent from the frequency itself;
- CW ←→ CCW: Positions of the accelerator elements are kept fixed → the constancy of the ratio of the leading field B_y to the B_x that produces a background to the EDM;
- High precision calibration of the equilibrium Lorentz factors of the CW to CCW beams by the precession of the spin in the horizontal plane;
- Extraction of the EDM signal from the frequency of the spin precession in the vertical plane is not affected by the spin precession in other planes
- In the course of revolution the spin stable axis may jitter about the radial axis but the jitter effect averages out

Physics case # 5: Longitudinal Spin is Imperative for Spin Crisis

Challenge of polarized DIS at eIC with longitudinally polarized deuterons: a must for the spin structure function of of neutrons

Siberian snakes are beyond question because of the impractically large field integrals

Ideas on working at the integer spin tune resonance:

First suggested by A.Kondratenko, Ya. Derbenev, Yu. Filatov, F. Lin, V. Morozov, M. Kondratenko, Y. Zhang, Preservation and control of the proton and deuteron polarizations in the proposed electron-ion collider at Jefferson Lab. Phys. Part. Nucl. 45 (2014) 323 , where 8-shaped rings do automatically have $\nu_s = 0$.

Yu. Filatov et al., Phys.Rev.Lett. 124 (2020) 194801; EPJ C80(2020) 778
H. Huang et al., PRAB 23 (2020) 021001

The frozen spin pEDM ring is also $\nu_s = 0$. SpinTra regime for EDM? (Senichev's bypass, also N. Piskunov)

Physics case # 5 cont'd: Spin-transparent mode at integer spin tune

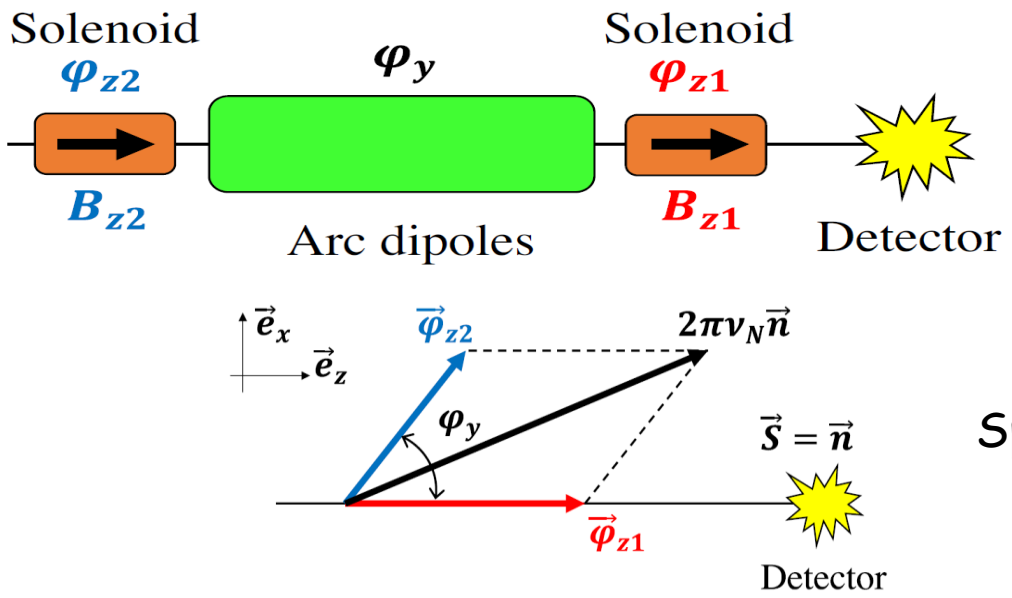
Recent talk by Yu. Filatov at Lab. High En. Physics

Degeneracy and instability of spin dynamics at integer spin tune

Provide the guiding B-field and stabilize spin by weak-field spin-navigator

New ideas on orbit correctors as spin navigators

Navigators provide resonance depolarization-free rotation of the spin stabilization axis



Spin is stabilized along the n-axis

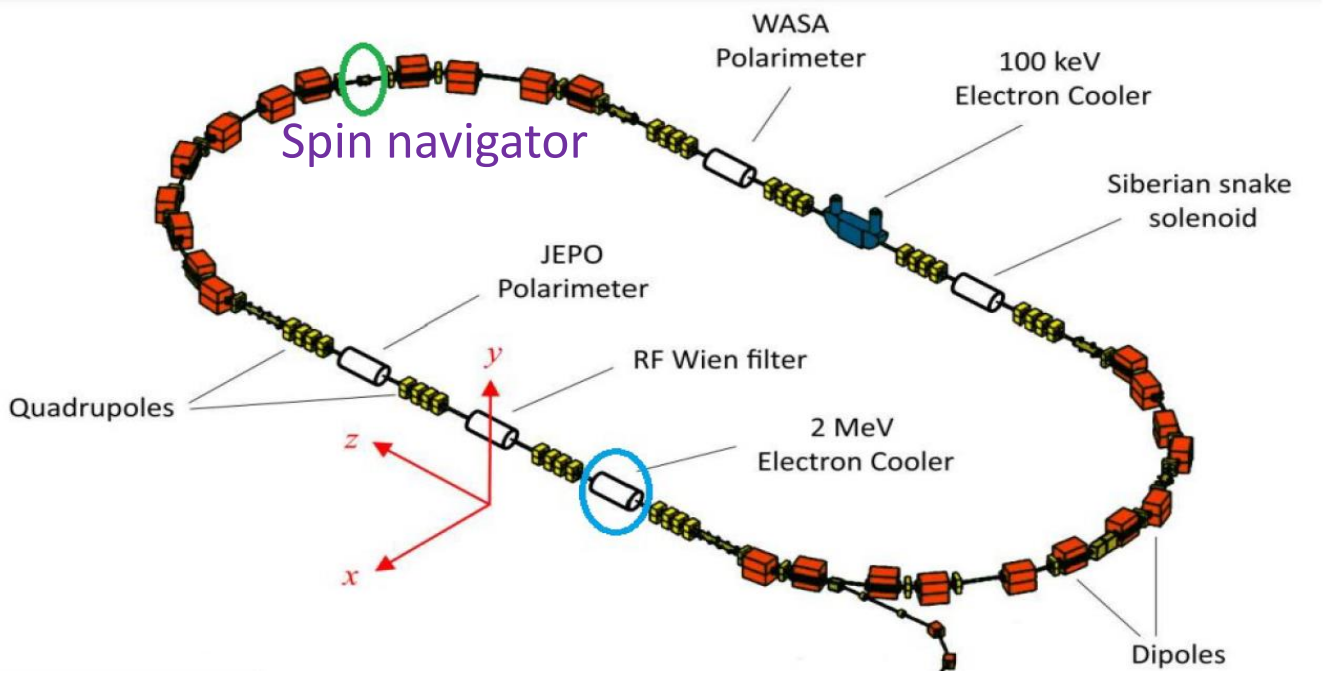
Summary and Outlook:

- Take advantage of the outstanding expertise in spin physics & equipment at JINR
- Excellent opportunities for fundamental P- and T-symmetry experiments at the NICA complex (need to upgrate polarimeters to horizonal beam polarization)
- NICA with bypass → window at EDM
- SpinTra: polarized deuterons are imperative for the spin crisis studies at NICA
- SpinTra: experimental test at Nuclotron is feasible (RSF grant 22-42-04419)
- SpinTra: supported by the RSF grant --- important for education of students for NICA: don't drag legs with the SPD
- EDM @ NICA: new ideas of quasi frozen spin and frequency domain method
- SpinTra at eIC --- the most promising solution for deuterons (spin crisis in QCD)
- Future JINR – FAIR cooperation in spin physics

Many thanks for your patience and attention !

Physics case #5: Missed opportunity: SpinTra DFG-RSF grant and Spin Transparency test at COSY

- All the equipment is already available at COSY
- Integer spin tune: no need to invoke Siberian snakes
- Spin navigators: when the application was filed one navigator solenoid was still missing
- A gift of God: 0.04 Tm solenoid was luckily found in the COSY lair !
- No extra expenditure beyond the DFG-RSF grant



Spin-transparency test at COSY: cont'd

- Polarized protons with T_p = 108 MeV
- Spin tune $G\gamma = 2$ (fractional spin tune $\nu = 0$)
- Good analyzing power
- Enthusiastic support by JEDI @ COSY

Minutes of 13th CBAC (COSY Beam Advisory Committee), August 26-27, 2021 (unofficial 2' comments by Yu. Filatov).

Proposal E11 Spin transp. mode

Spin transparency is an idea to operate storage rings at integer spin tune. Using so-called "spinnavigators" the method promises to achieve stable spin orientation at any desired orbit position. COSY is the only place where this method can be studied for many years to come. CBAC encourages the proponents to present a detailed run-time request within the next session.

Why not to invite FAIR to cooperate in spin physics at NICA?

- Zero financial commitments by JINR to support SpinTra running the spin-transparency test at COSY (all covered by the DFG-RSF grant 22-42-04419)
- Flies in the ointment: IKP has become a part of GSI and new strickt guidance in place for CBAC from the new boss (FAIR @ GSI)
- Priority treatment of beam time requests with FAIR oriented strategic (?) applications
- COSY shut down after 2024, beam time down by 50% from 2021 on
- Cooperation shall enhance the chances of the SpinTra beam time at COSY in 2022
- Take advantage of the JEDI @ COSY invaluable experience in spin physics
- Good chances to inherit/use at NICA parts of the idling equipment from COSY?