STORI05
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EDM SEARCH

RESONANCE METHOD OF EDM MEASUREMENTS IN STORAGE RINGS

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(on behalf of the EDM collaboration)

THE BASIC FORMULAS FOR THE THREE EDM METHODS

$$\frac{d\vec{s}}{dt} = \left[\vec{s} \times \vec{\omega}_s\right] \qquad \vec{\omega}_{\vec{s}-\vec{p}} = \vec{\omega}_a + \vec{\omega}_e$$

$$\vec{\omega}_a = \frac{e}{mc}\left[a\vec{B} + \left(\left(\frac{mc}{p}\right)^2 - a\right)\vec{v} \times \vec{E}\right]$$

$$\vec{\omega}_e = \frac{e}{2mc}\eta\left[\vec{E} + \vec{v} \times \vec{B}\right] \approx \frac{e}{2mc}\eta\left[\vec{v} \times \vec{B}\right]$$

For deuterons, *a=-0.14301*

$$\frac{ds_V}{dt} = \left[\vec{s} \times \vec{B}\right]_V = \frac{e}{2mc}\eta\left[\vec{s} \times \left[\vec{v} \times \vec{B}\right]\right]_V = -\frac{e}{2mc}\eta \cdot v \cdot B \cdot s_L$$

RESONANCE METHOD OF EDM MEASUREMENT AND THE "TWO HALF-BEAMS TECHNIQUE"

In this method, $\omega_a = (e/mc)aB = (e/mc)a\gamma\omega_C \neq 0$

There are no electric fields, except the RF fields of the usual RF cavities.

Instead,

WE INTRODUCE FORCED SYNCHROTRON OSCILLATIONS, THE SAME FOR ALL PARTICLES, WITH THE FREQUENCY AND PHASE OF G-2.

Resonance EDM Ring

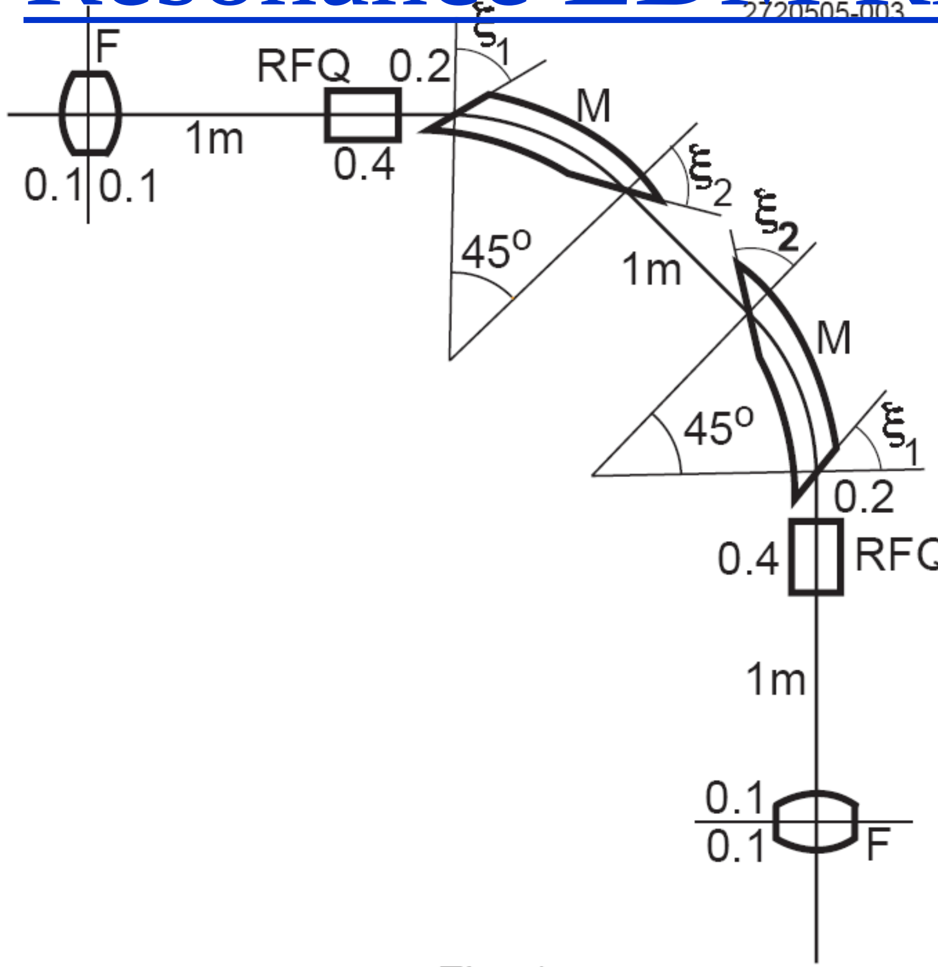


Fig. 1

$\frac{1}{4}$ of an EDM ring

M - Magnets (focusing edges, homogeneous B)

RFQ - RF quadrupoles, $(\partial B/\partial x)_{max}$ ~20 gauss/cm

F - usual focusing quadrupoles

R = 1.167488m (for B = 2T)

THE VELOCITY AND THE SPIN,

$$v = v_0 + (\Delta v)_{free} \cos(\omega_L t + \alpha_L) + (\Delta v)_F \cos(\omega_a t + \varphi_a)$$

and

$$s_L = s_{L0} \cos(\omega_a t + \varphi_a)$$

partially oscillate in resonance:

$$\frac{ds_y}{dt} = \omega_e s_L = -\eta \frac{eB_V}{2mc} s_{L0} \cos(\omega_a t + \varphi_a) \cdot \left[(\Delta v)_F \cos(\omega_a t + \varphi_a) + (\Delta v)_{free} \cos(\omega_L t + \alpha_L) + v_0 \right]$$

$$= -\eta \frac{eB_V}{4mc} s_{L0} (\Delta v)_F \quad \text{+ NON-RESONANCE TERMS}$$

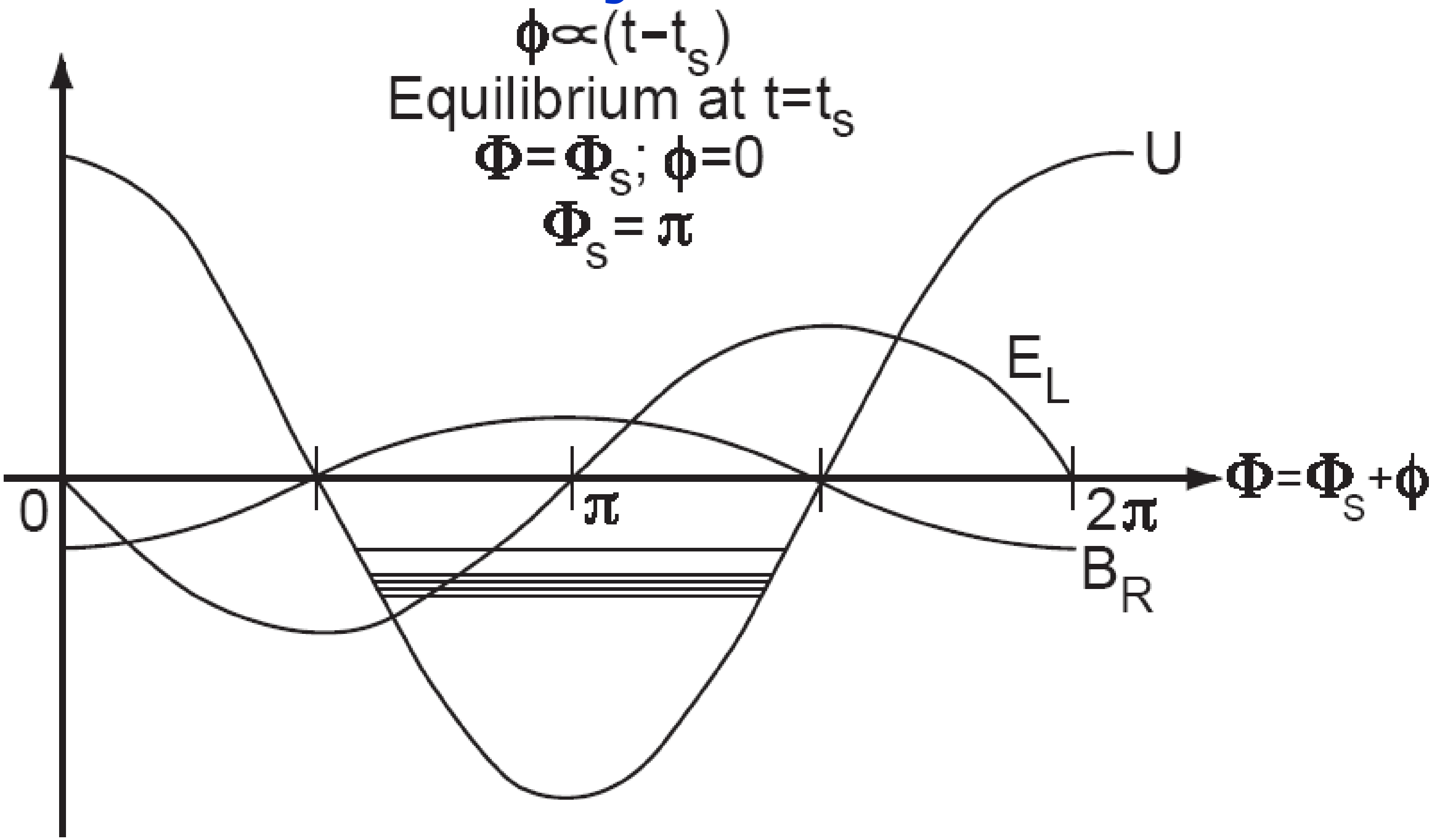
THUS,

$$s_V - s_{V0} \approx -\eta \frac{eB_V}{4mc} s_{L0} (\Delta v)_F t$$

(In our deuteron EDM ring, $(\Delta v)_F / v_0 = 0.02$, $R \sim 1m$, $B_V = 2T$

The goal is $\delta d_D \sim 10^{-29}$, $\delta\eta \sim 2 \times 10^{-15}$)

RF-cavity Parameters

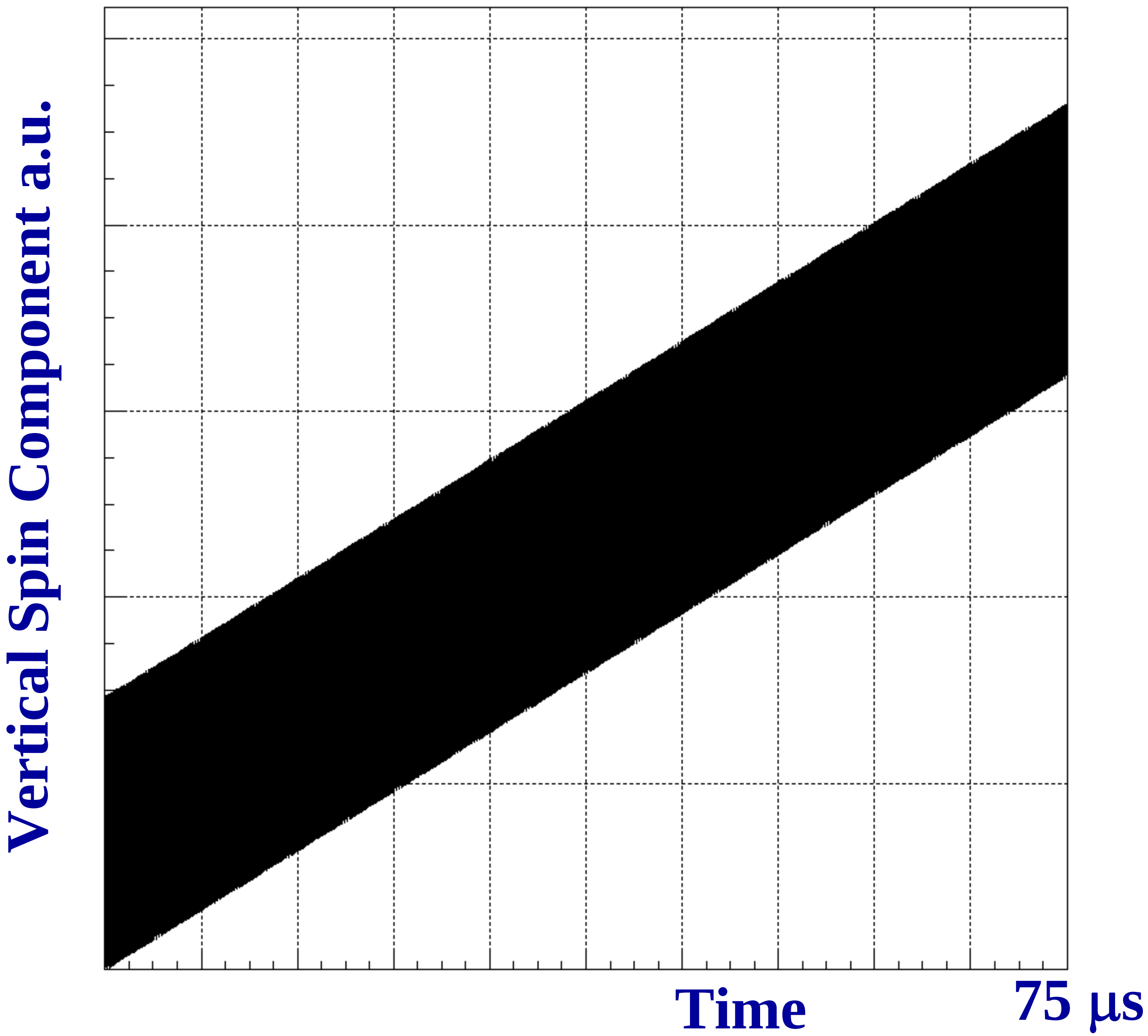


U - Potential energy of synchrotron oscillations.

E_L - longitudinal electric field.

B_R - radial magnetic field perturbation.

Vertical Spin Component with Velocity Modulation (longer Time)



Betatron Parameters

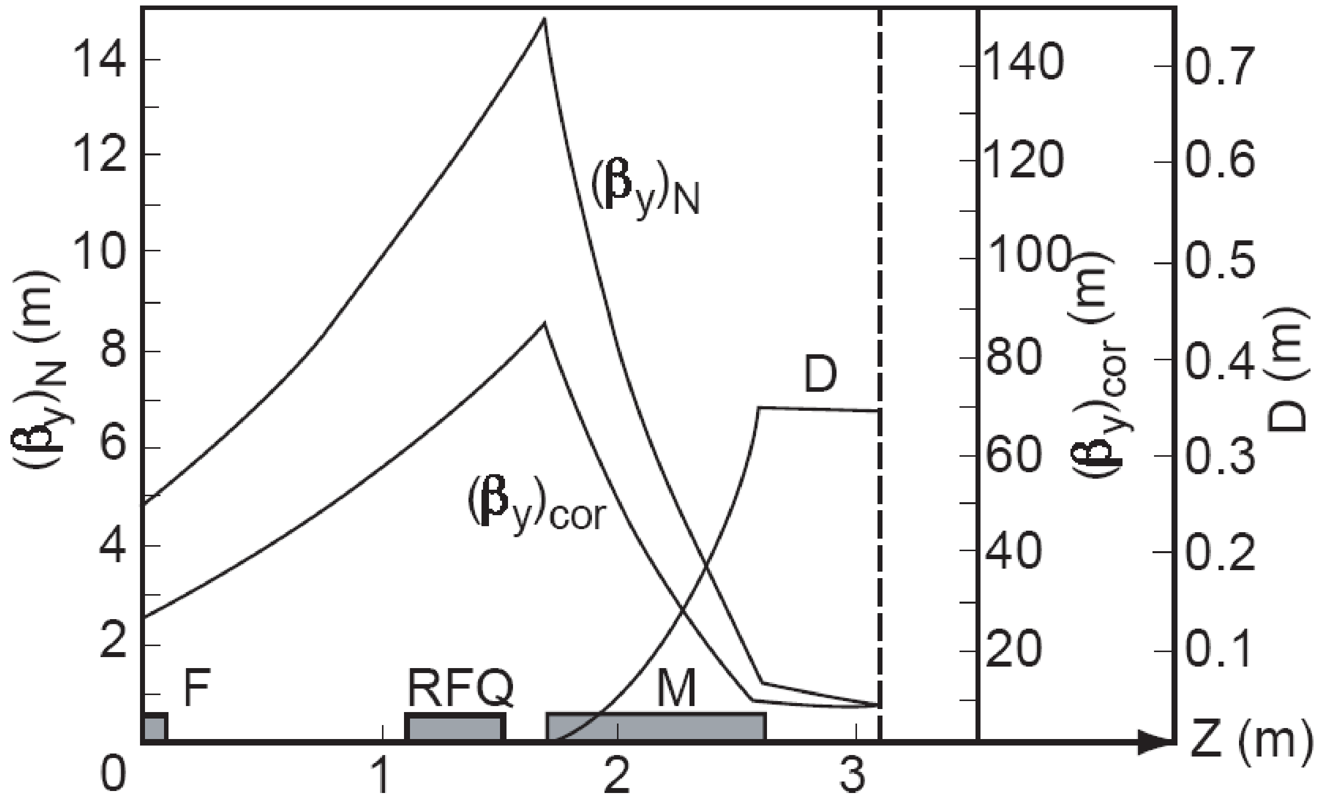


Fig. 3 (1/8 of the ring).

$(\beta_y)_N$ corresponds to the "normal" half-beam.

$(\beta_y)_{cor}$ corresponds to the "correcting" half-beam,

$\nu_y = 0.1526$

WHAT ABOUT RADIAL MAGNETIC FIELD PERTURBATIONS IN THE DIPOLES?

THIS IS THE ONLY SERIOUS FIRST-ORDER EFFECT IMITATING EDM.

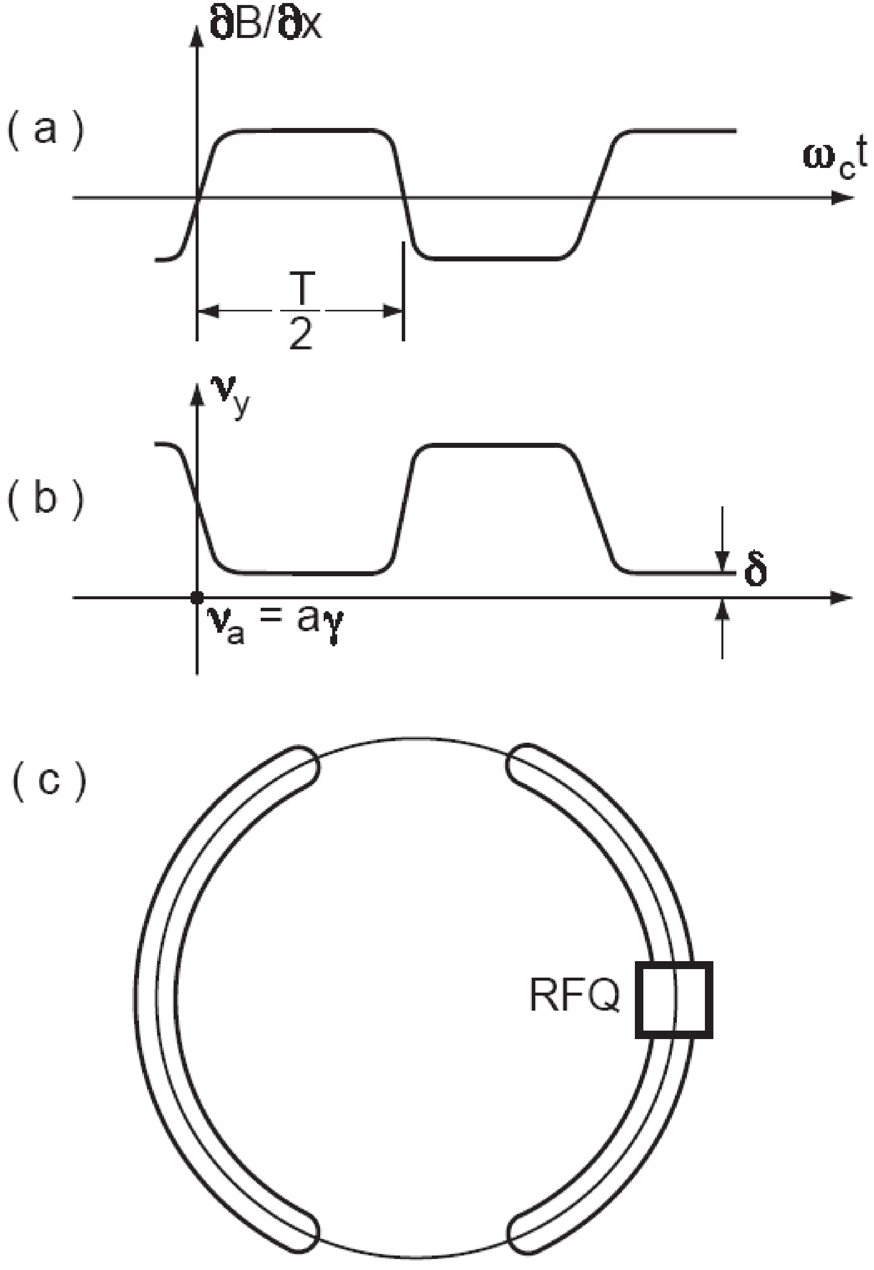
For $10^{-29}\, e \cdot cm$

$$\sqrt{\langle \theta_B^2 \rangle} \equiv \sqrt{\langle B_R^2 \rangle} / B_V < (0.3 - 0.5) \times 10^{-11}$$

WE WILL BE ABLE TO CORRECT THIS PERTURBATION WITH THE HELP OF THE TWO HALF-BEAMS TECHNIQUE OF THE FAST CORRECTIONS.

We have incorporated into this technique an old idea (of Y.S.) of using observations of the vertical component of spin itself to correct perturbations imitating EDM.

Two half beam technique



FAST CORRECTION OF RESONANCE PERTURBATIONS IMITATING EDM

"Fast" means ~ every 100ms, while one fill of the ring lasts ~5min (= the designed spin coherence time).

- **WE HAVE TWO HALF-BEAMS—ONE "NORMAL" AND ONE "CORRECTING"—WITH TWO DIFFERENT VERTICAL BETATRON TUNES, $(\nu_y)_N$ AND $(\nu_y)_{cor}$, RESPECTIVELY.**

- **IN THE "NORMAL" HALF-BEAM, WHICH IS DESIGNED FOR THE EDM MEASUREMENT,**

$$(\nu_y)_N > 1$$

- **IN THE "CORRECTING" HALF-BEAM, WHICH IS DESIGNED TO EXPOSE HIGHLY ENHANCED SPIN RESONANCE PERTURBATIONS (PERMITTING US TO CORRECT THEM ON THE BASIS OF THIS ENHANCED EXPOSITION),**

$$(\nu_y)_{cor} = \nu_a + \delta$$

ENHANCEMENT AT SUCH A BETATRON TUNE IS CAUSED BY:

1. The increase of the Courant β -function, $\beta^2_{cor} / \beta^2_N \sim 45$.

2. The proximity of the vertical *betatron* resonance at $\nu_y = \nu_a$.
This strong beam resonance is caused by the B_R-field oscillations (with the g-2 frequency) described above. Under this resonance, the correcting half-beam performs enhanced vertical oscillations with the g-2 frequency. These oscillations enhance the radial magnetic field met by the particle *along the perturbed orbit*. The combined—from (1) and (2)—enhancement factor for this perturbation (more precisely, for its influence on spin) can reach ~3000. Then it is rather obvious how to use it:

(a) Every 100ms, say, observe a non-EDM growth of $\left|\langle s_V\rangle\right|$ and

$$\langle s_V^2\rangle - \langle s_V\rangle^2$$

in the normal half-beam and correct perturbation there. Then,

(b) Repeat the same operations in the correcting half-beam.

Summary

- It looks quite doable!