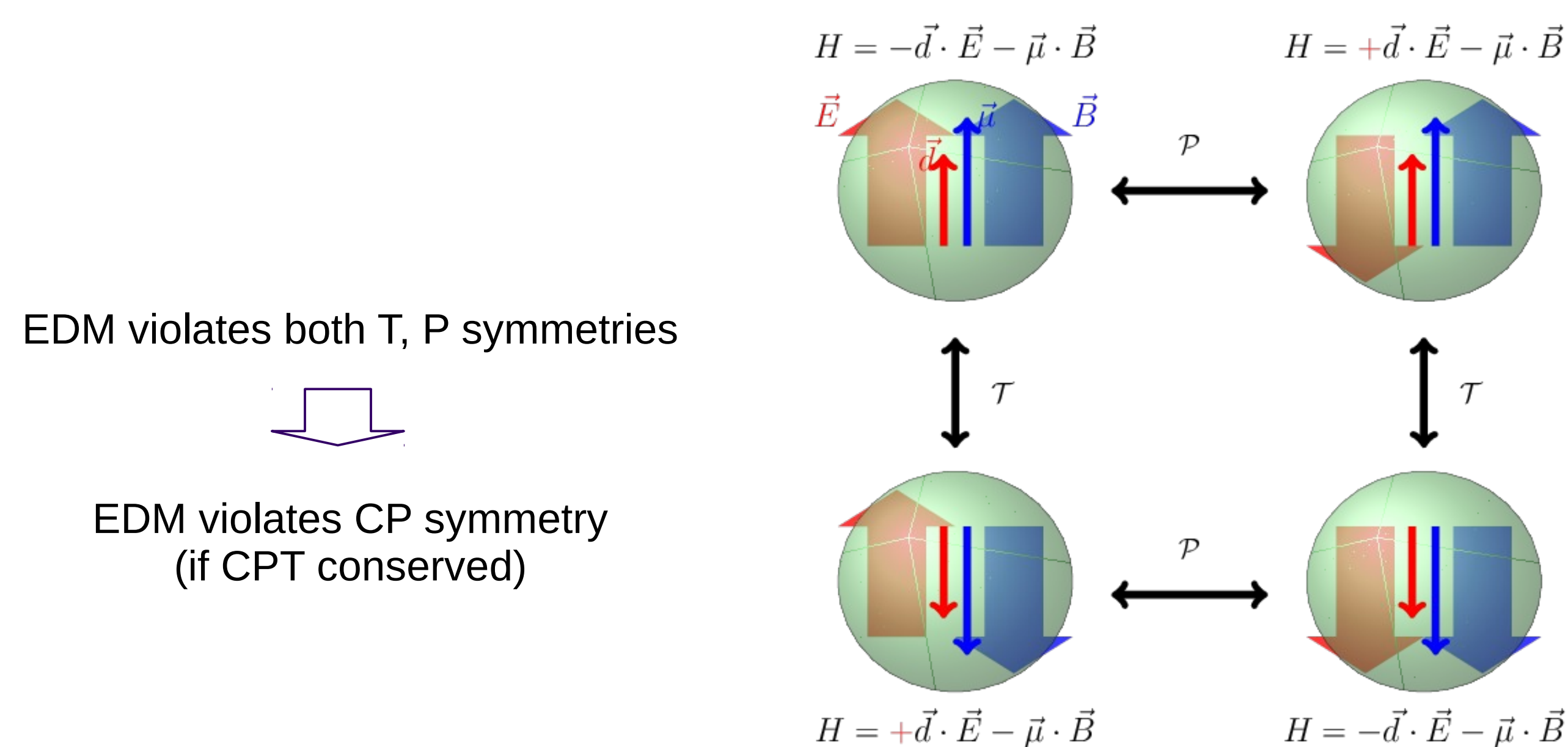# Università degli Studi di Ferrara

**JEDI**

# THE SEARCH FOR ELECTRIC DIPOLE MOMENTS OF CHARGED PARTICLES USING STORAGE RINGS

VERA SHMAKOVA FOR THE JEDI COLLABORATION

## MATTER – ANTIMATTER ASYMMETRY

Why is our universe is matter dominated?

• Experiment predicts[2]　　　$\dfrac{n_b - n_{\bar{b}}}{n_\gamma} \sim 10^{-10}$

• Expectations from SCM[3,4]　$\dfrac{n_b - n_{\bar{b}}}{n_\gamma} \sim 10^{-18}$

• Criteria for preference of matter, A. Sakharov[5] (1967):
  • CP violation



$H = -\vec{d}\cdot\vec{E} - \vec{\mu}\cdot\vec{B}$　　$H = +\vec{d}\cdot\vec{E} - \vec{\mu}\cdot\vec{B}$

$\mathcal{P}$　　$\mathcal{T}$

EDM violates both T, P symmetries

EDM violates CP symmetry (if CPT conserved)

$H = +\vec{d}\cdot\vec{E} - \vec{\mu}\cdot\vec{B}$　　$H = -\vec{d}\cdot\vec{E} - \vec{\mu}\cdot\vec{B}$

> EDM may possibly contain the missing piece of the puzzle to explain the matter-antimatter asymmetry

## COSY

Cooler Synchrotron COSY (Jülich, Germany)



WASA Detector
Electron Cooler
Siberian Snake
Detector
RF Wien Filter
Injection
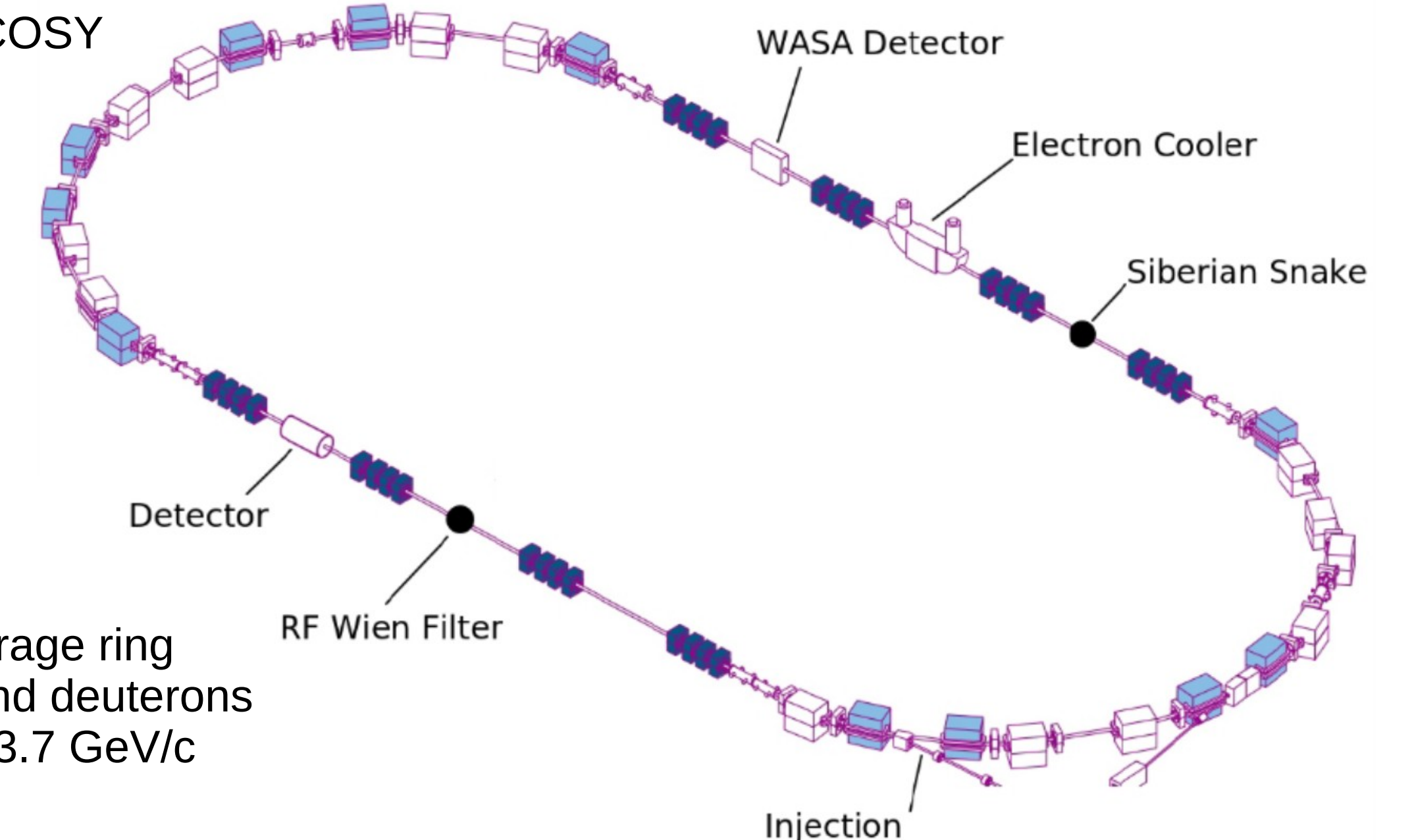
• purely magnetic storage ring
• polarized protons and deuterons
• momenta p = 0.3 – 3.7 GeV/c

## INVARIANT SPIN AXIS



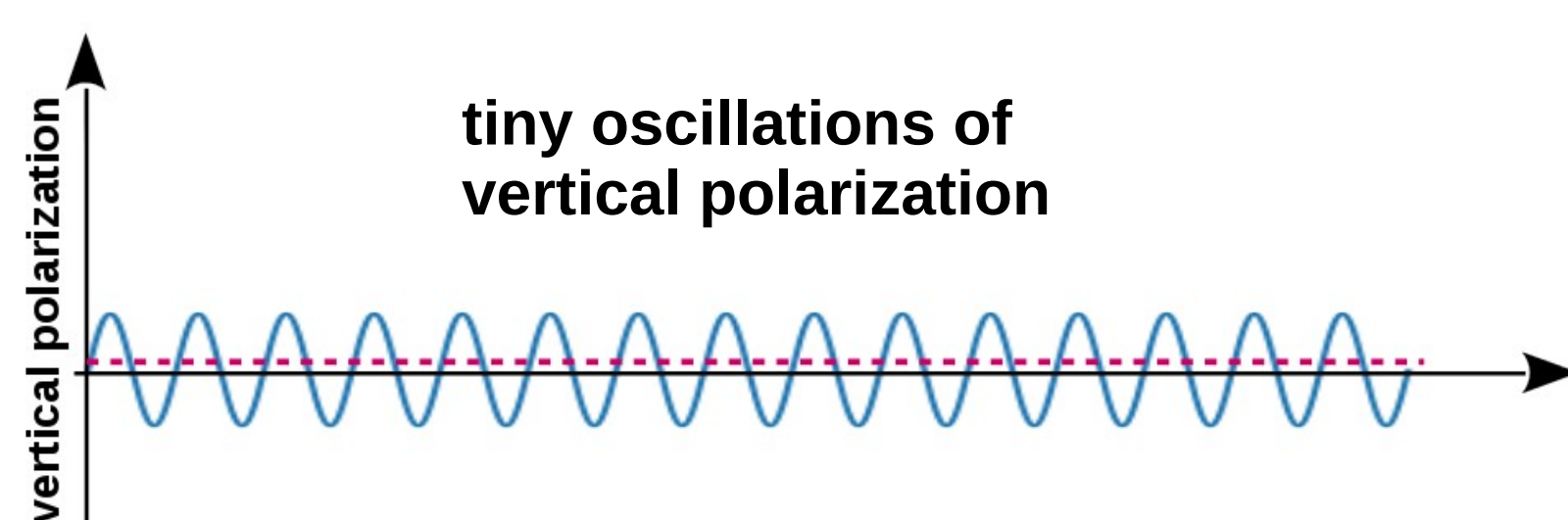EDM absent　　　Pure EDM effect　　　EDM + magnetic misalignments
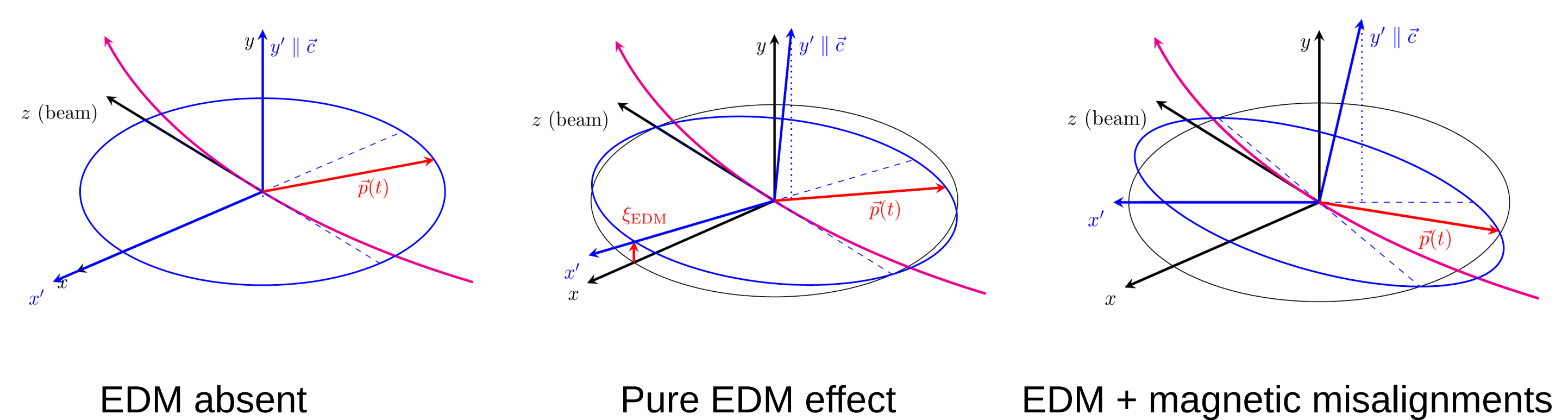
## SPIN MOTION IN MAGNETIC STORAGE RING

$$\frac{d\vec{S}}{dt} = [\vec{\Omega}_{MDM} - \vec{\Omega}_{cycl} + \vec{\Omega}_{EDM}] \times \vec{S}$$

$$\vec{\Omega}_{MDM} - \vec{\Omega}_{cycl} = -\frac{q}{m}\left\{ G\vec{B} - \left(G - \frac{1}{\gamma^2 - 1}\right)\frac{\vec{\beta}\times\vec{E}}{c} \right\}$$

$$\vec{\Omega}_{EDM} = -\frac{\eta q}{2mc}\left\{ \vec{E} + c\,\vec{\beta}\times\vec{B} \right\}$$

access to EDM
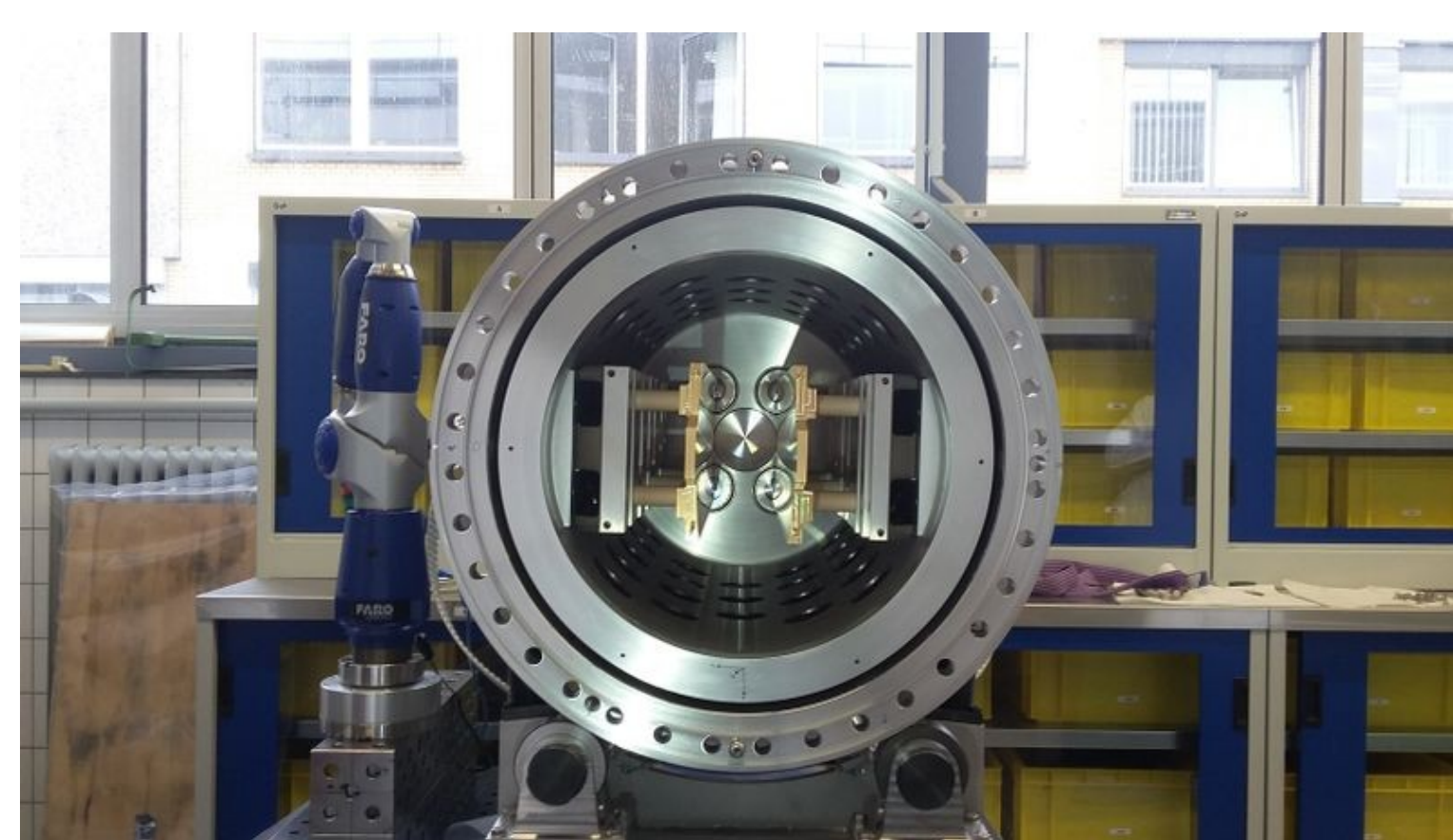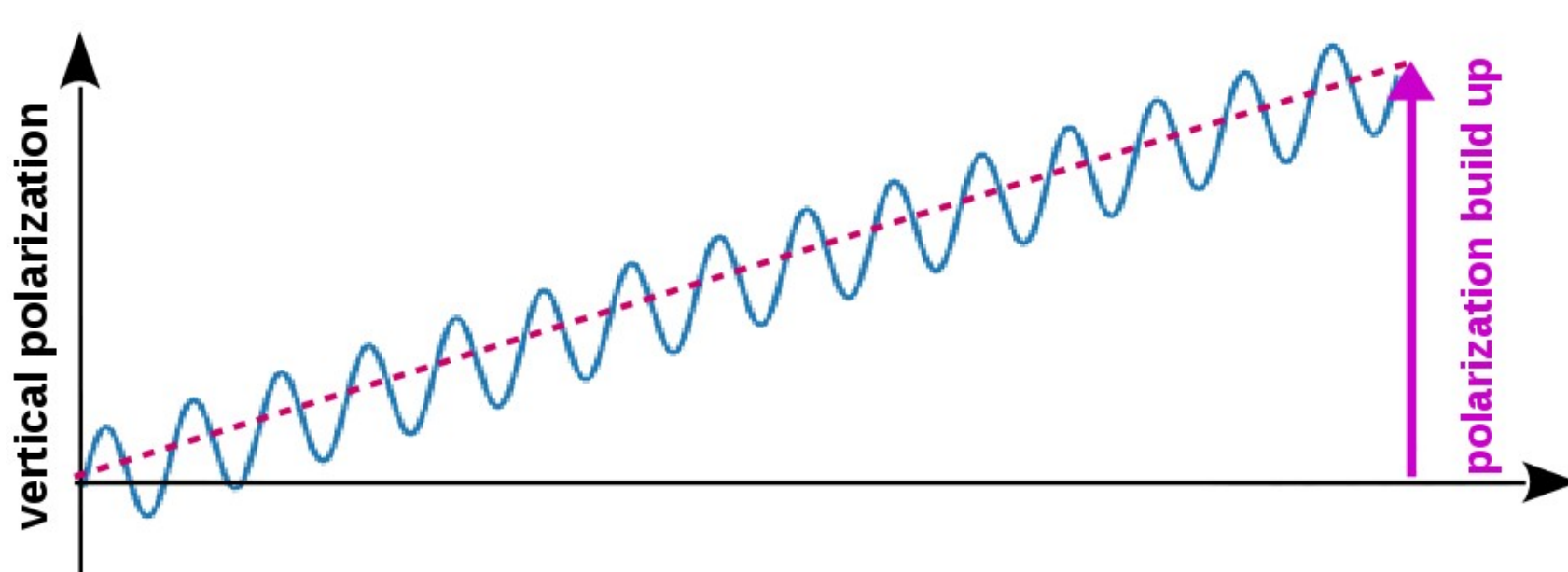


**tiny oscillations of vertical polarization**

In the magnetic ring
momentum ↑↑ spin ⟹ spin kicked up
momentum ↑↓ spin ⟹ spin kicked down

**no accumulation of vertical asymmetry**

RF Wien filter[6,7]:

• Lorentz force　$\vec{F}_L = q(\vec{E} + \vec{v}\times\vec{B}) = 0$

• $\vec{B} = (0, B_y, 0)$　$\vec{E} = (E_x, 0, 0)$

• phase lock between spin precession and RF Wien filter

**polarization build-up**



## EXPERIMENT AND RESULTS

• Coherent ensembles in ring plane
  ⟹ spin coherence time has to be longer then a measurement

• Feedback monitors spin precession phase and adjust WF frequency to maintain the relative phase between spin precession and Wien filter RF

• 8 high-speed RF switches to gate the WF power for one of two bunches
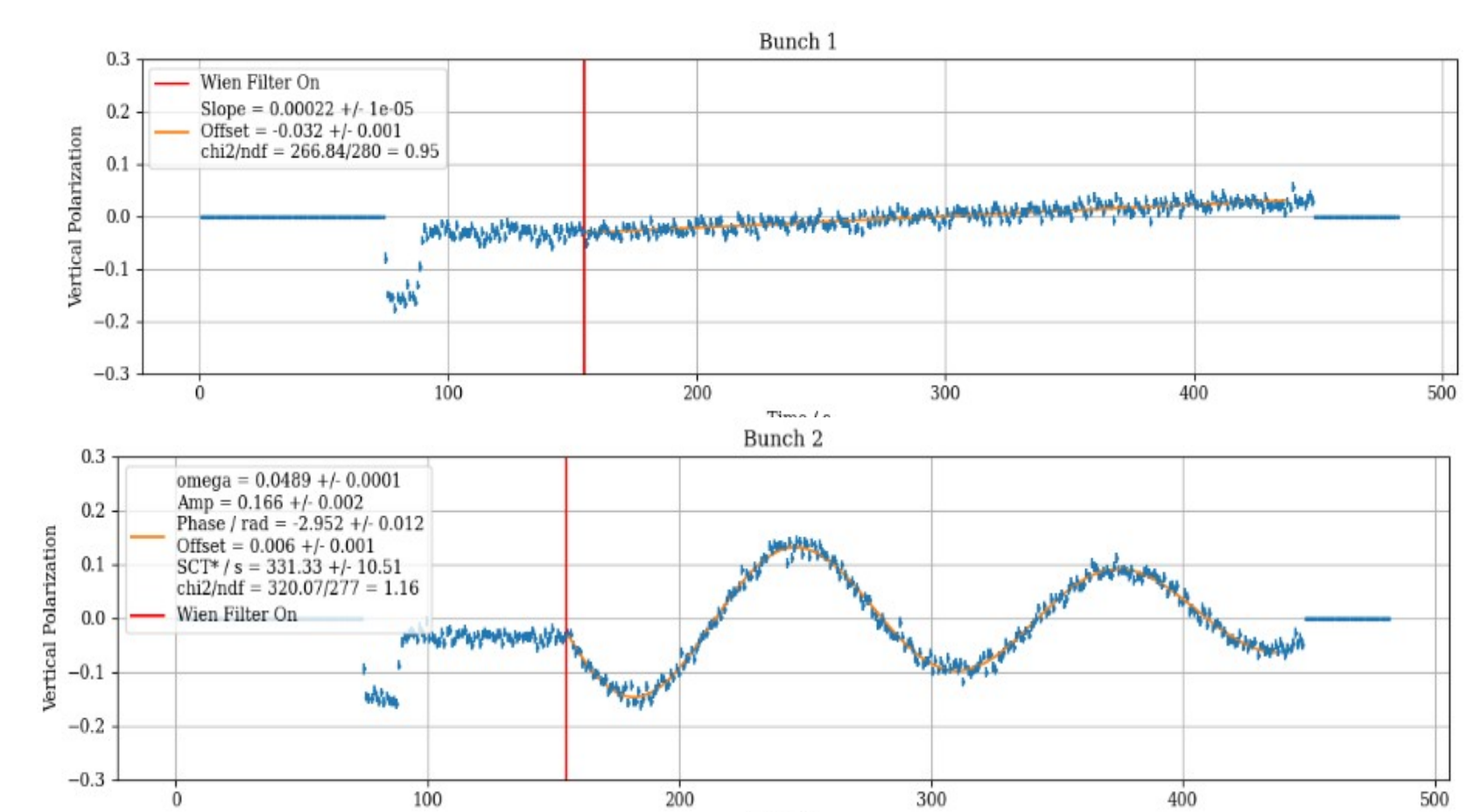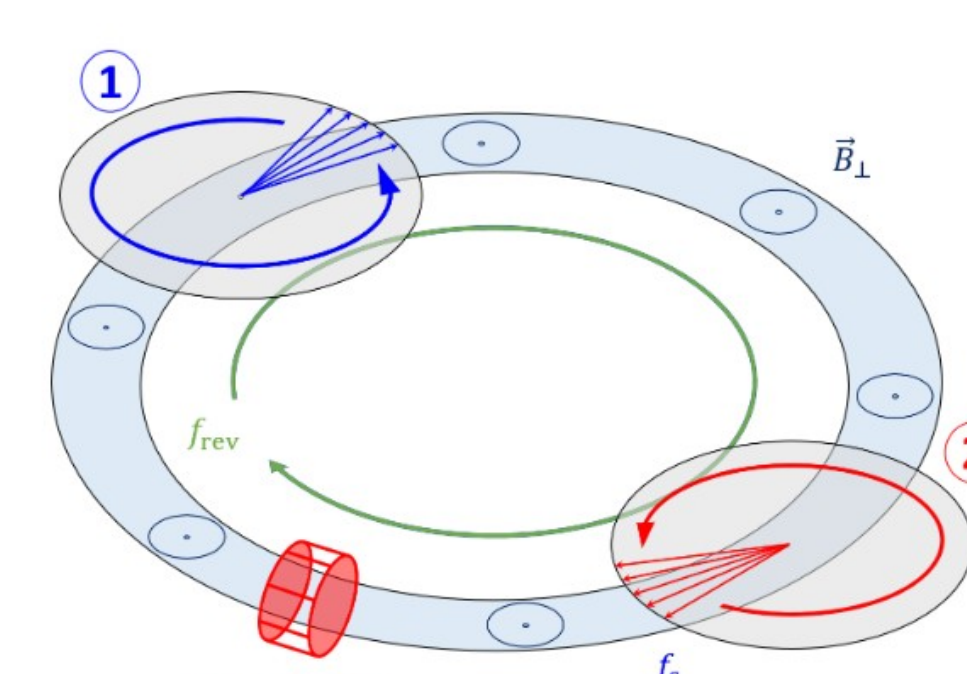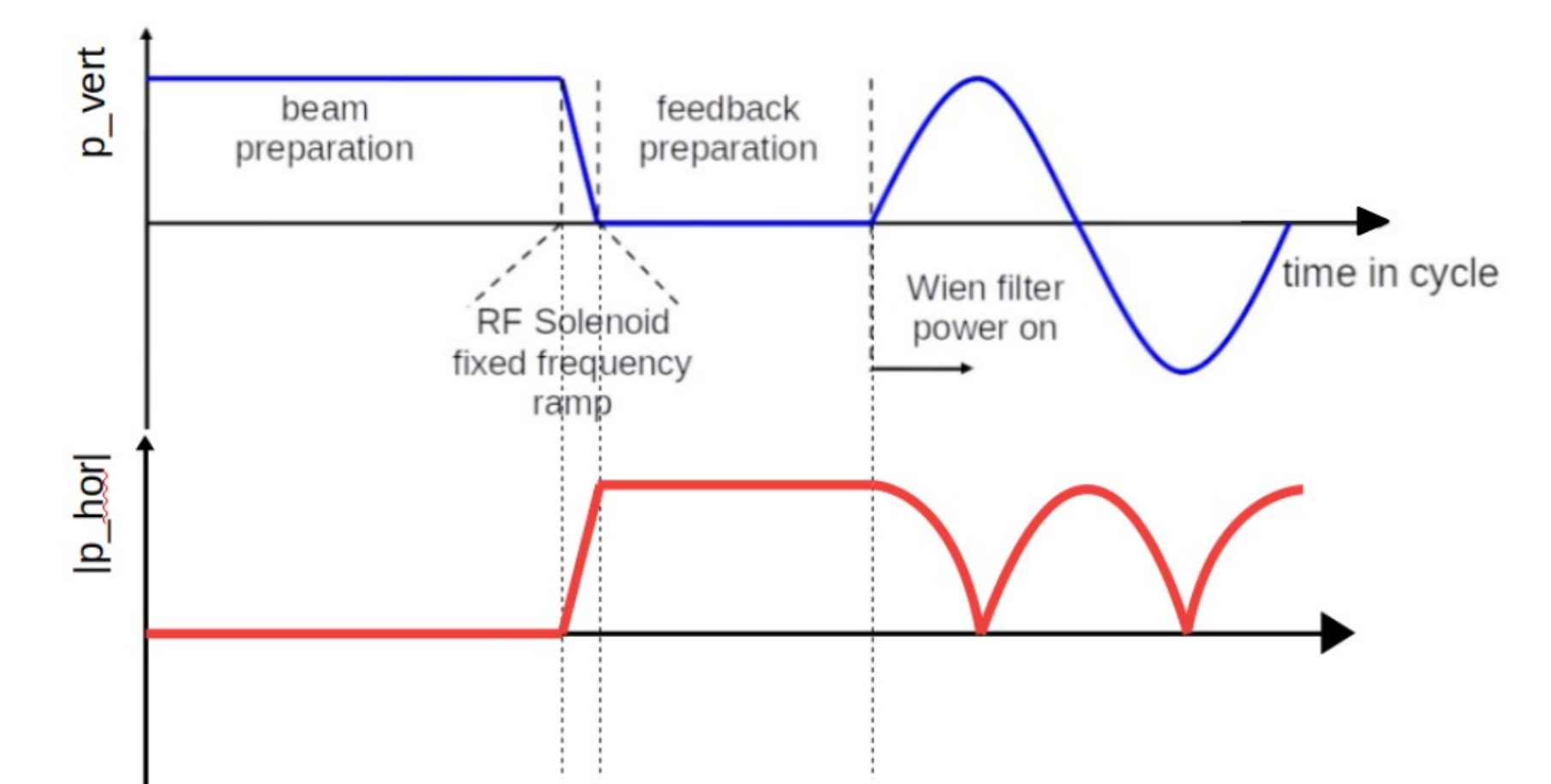




• Capable of short switch time ~ few ns

• Bunch ② sees the full power of the RF Wien filter and oscillate

• Bunch ① is used for the feedback system to lock the phase between spin precession and Wien filter RF

• Minimum of the surface shows orientation of invariant spin axis:

• Orientation of precession axis without EDM effect will come out of spin tracking calculations
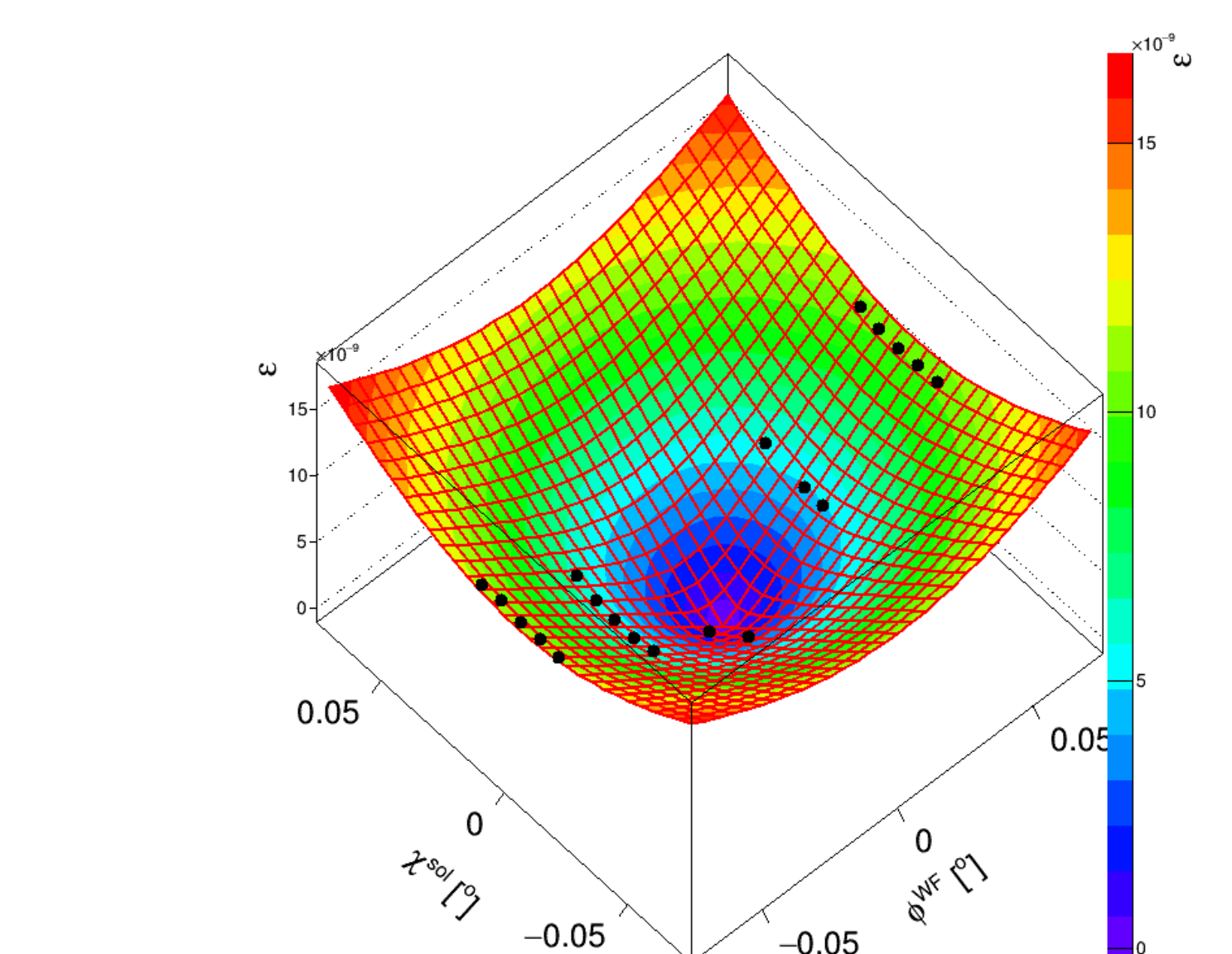
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## SUMMARY

• Charged hadron EDMs: Possibility to find sources of CP violation and to explain matter-antimatter asymmetry in the universe.
• Precursor experiments performed as a proof of principle of EDM measurement at storage rings. Analysis of data ongoing.
• New method of manipulating the polarization for one of two bunches in the ring was developed and performed
• CERN Yellow Report prepared by CPEDM collaboration[1].
• COSY remains a unique facility for such studies.