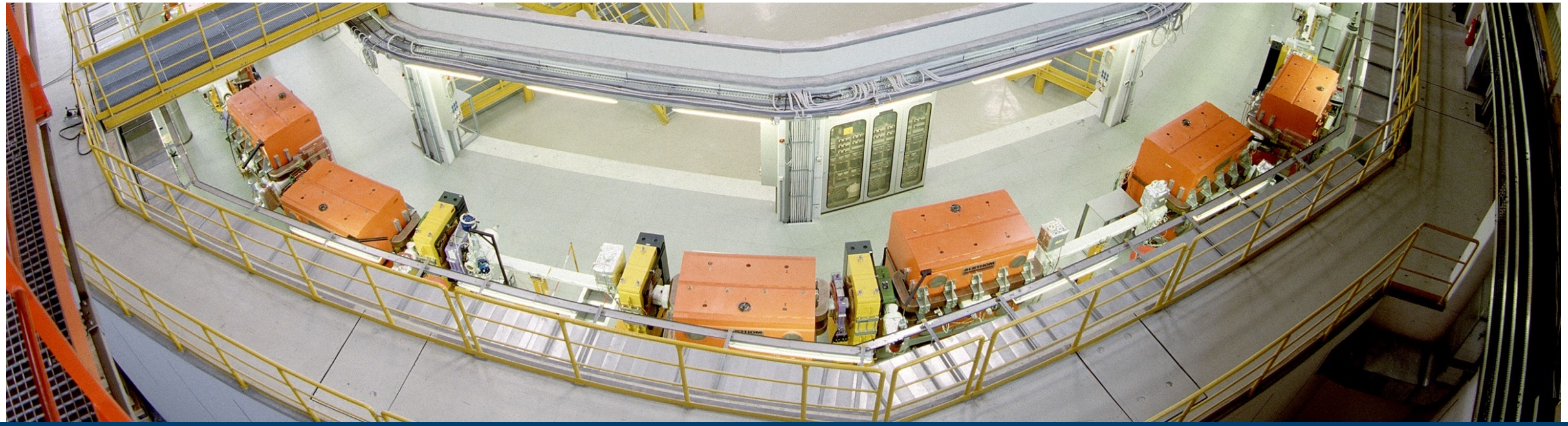

THE SEARCH FOR ELECTRIC DIPOLE MOMENTS OF CHARGED PARTICLES IN STORAGE RINGS

DPG Spring Meeting Dresden

22.03.2023 I ACHIM ANDRES (ON BEHALF OF JEDI)

JEDI

Physics Institute III B | RWTH AACHEN UNIVERSITY

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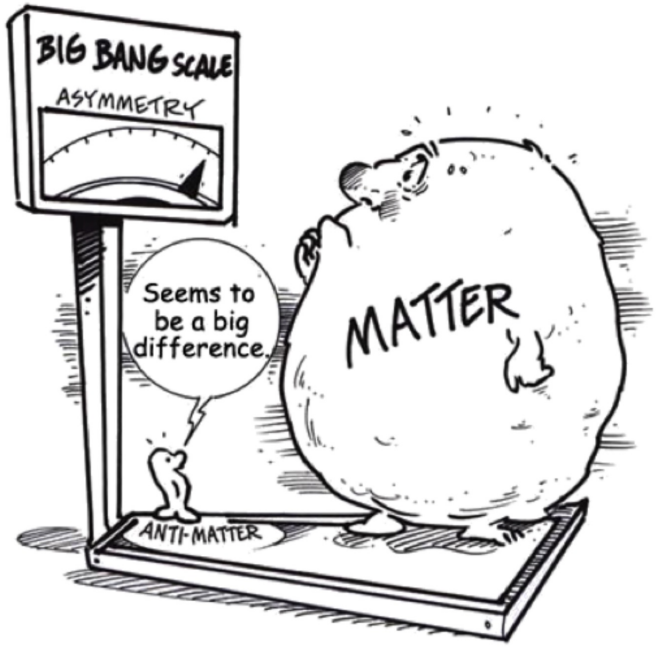
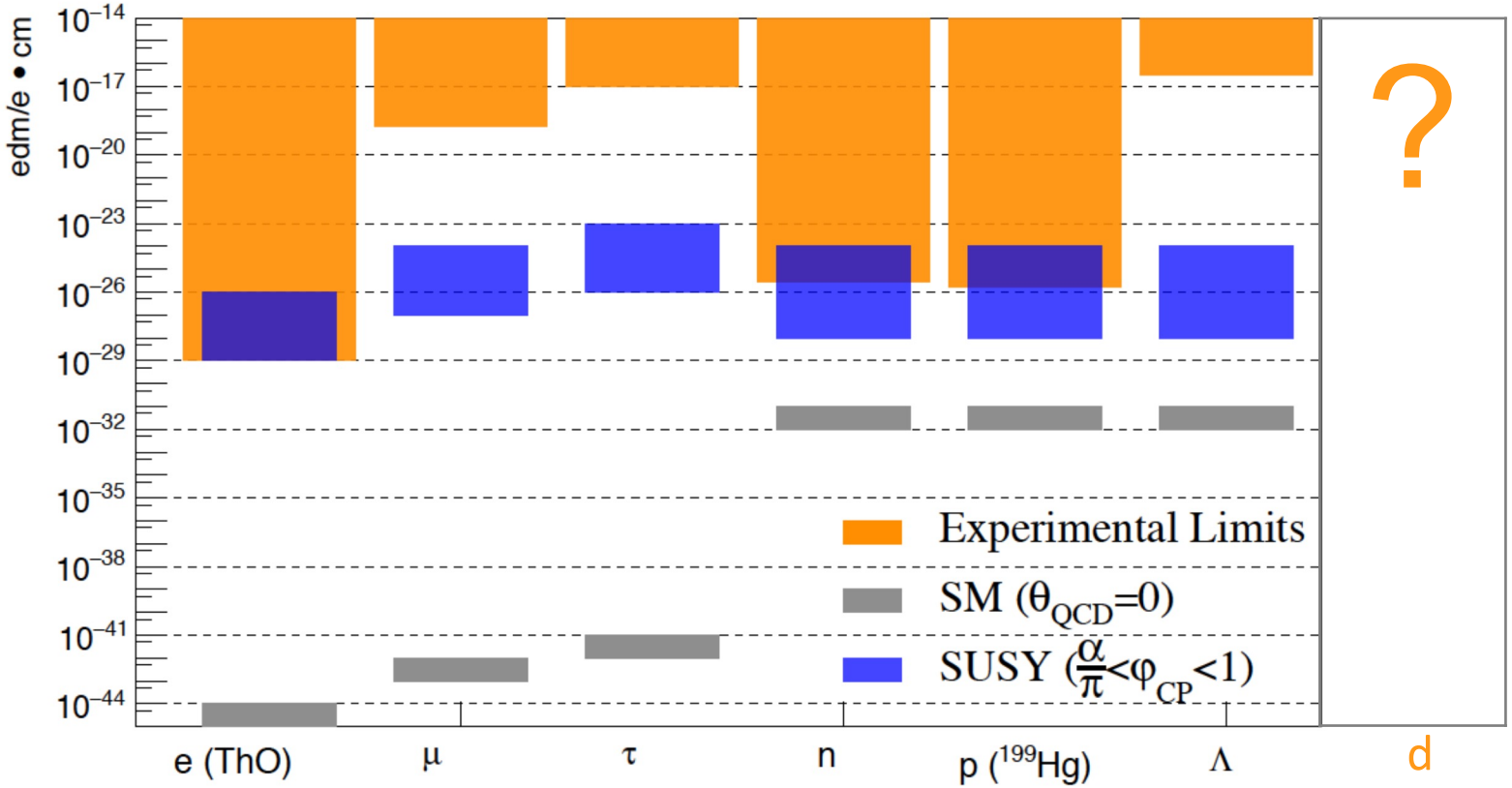
EDM LIMITS

JEDI Collaboration (2011) – Juelich Electric Dipole Moment Investigations





- According to A. Sakharov: **CP Violation** is needed
- EDMs of fundamental particles are CP violating
- EDM is a ***vectorial*** property aligned with the particles spin

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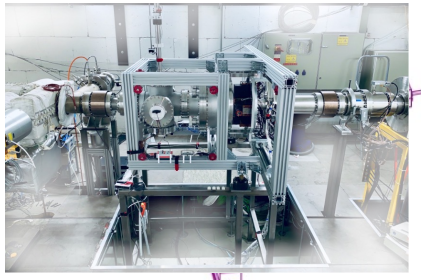
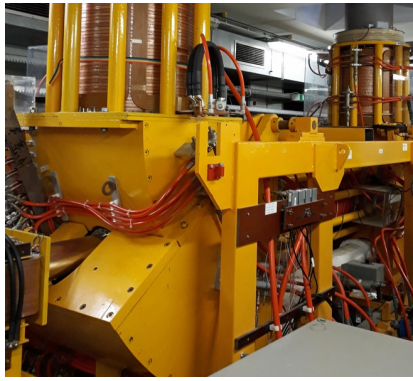
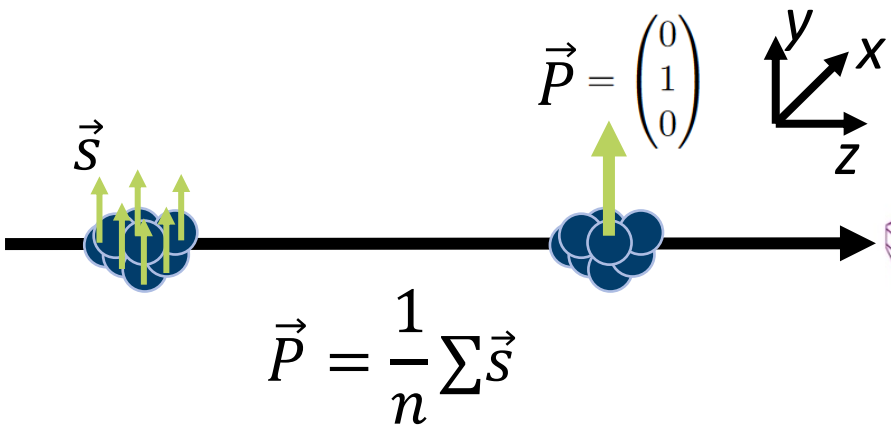
COSY - COOLER SYNCHROTRON

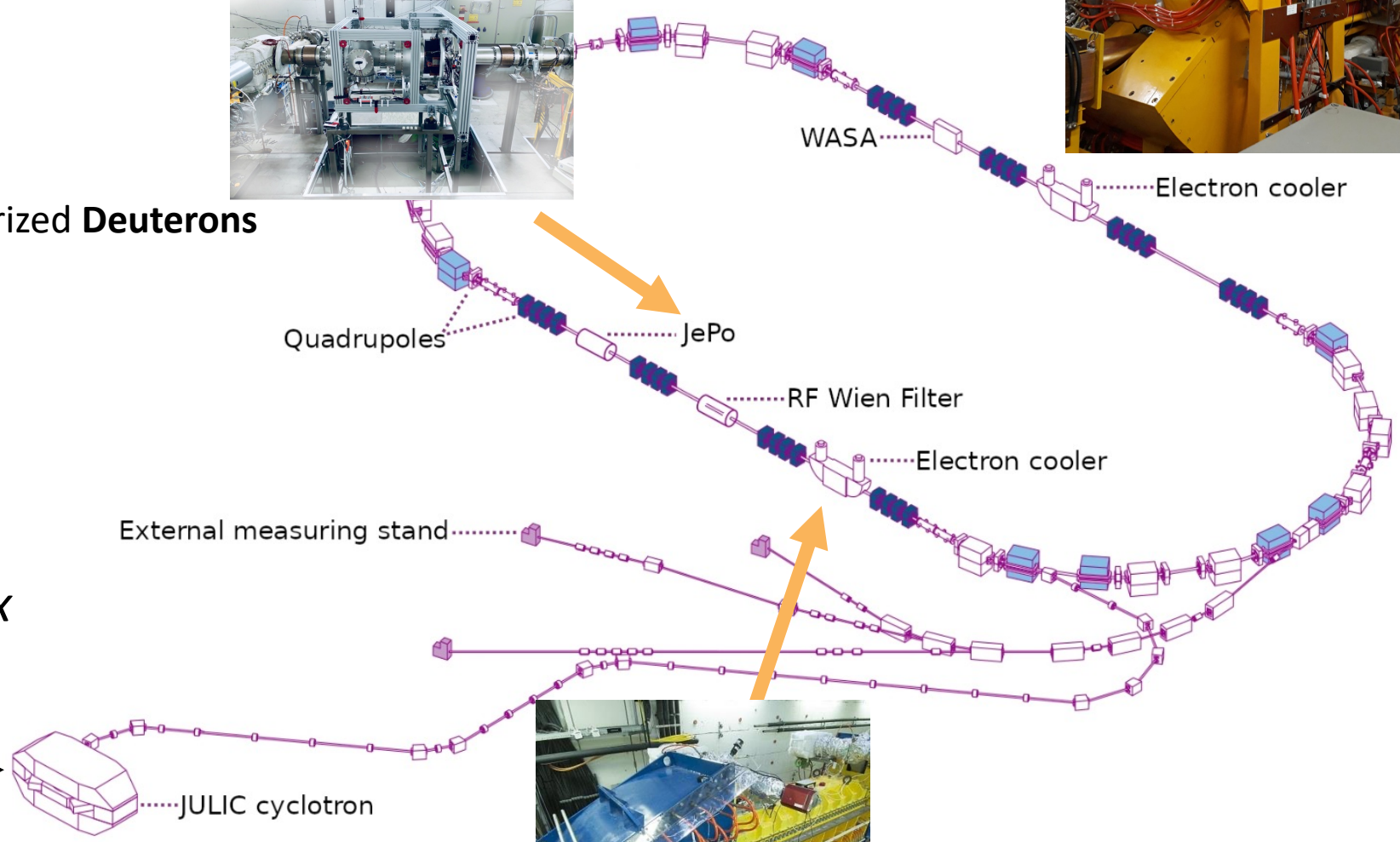
Overview

- Circumference 184 m
- Accelerate and Store **Polarized** / Unpolarized **Deuterons** and Protons
- $p = 0.3 \; - 3.7$ GeV/c
- Excellent Beam Quality
- Hadron Physics / **Precision** Experiments









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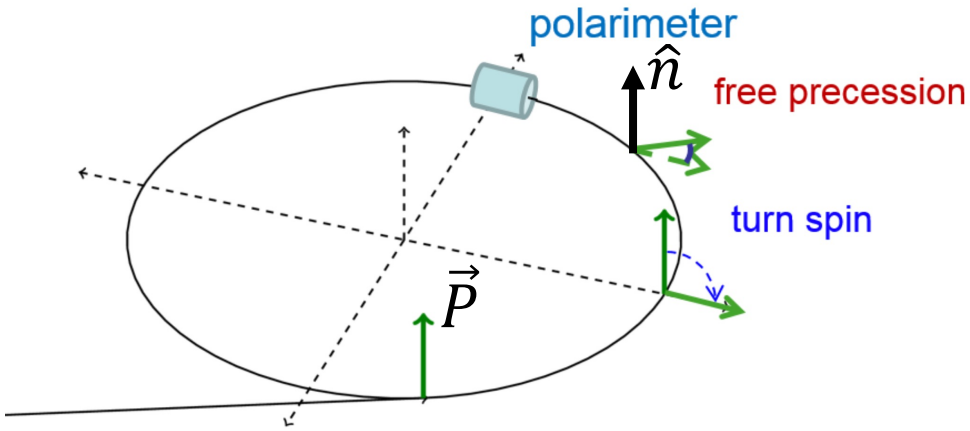
MEASUREMENT PRINCIPLE

- Measure **influence** of **EDM** on beam **polarization**
- **Injection** of vertically **polarized** deuteron beam
- **Rotate** polarization into **accelerator plane**
- COSY: **Magnetic** Ring → Polarization Vector **precesses** around invariant spin axis $\hat{n}$



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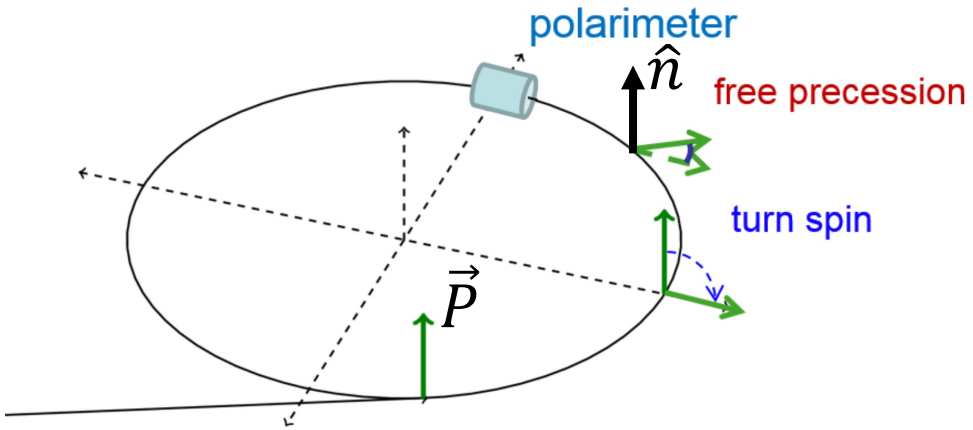
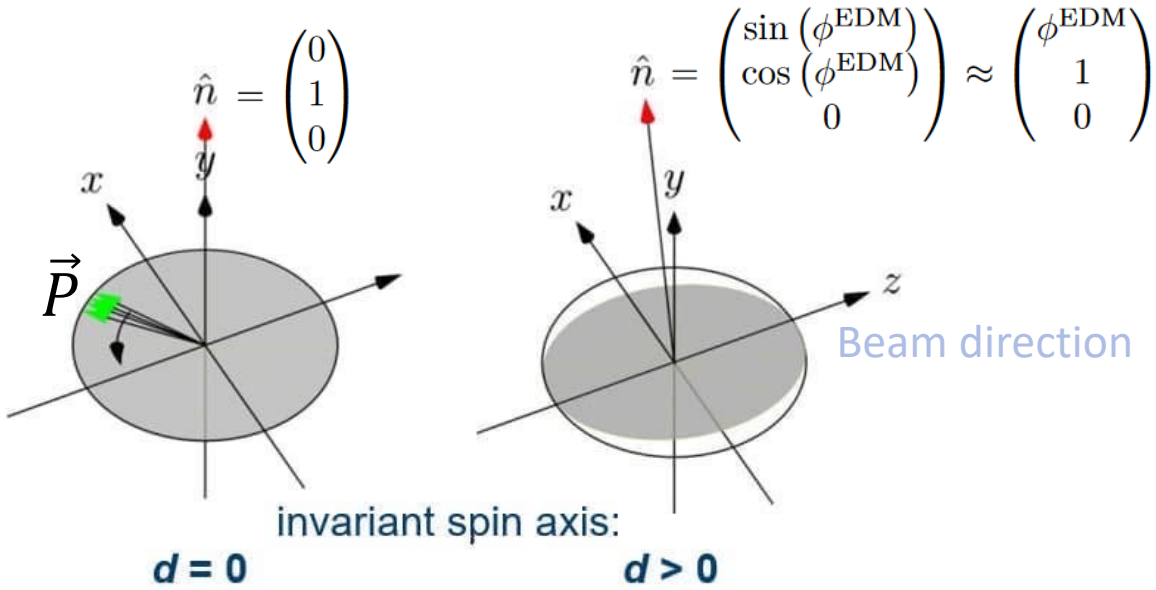
- **Goal**: Determination of the **orientation** of $\hat{n}$





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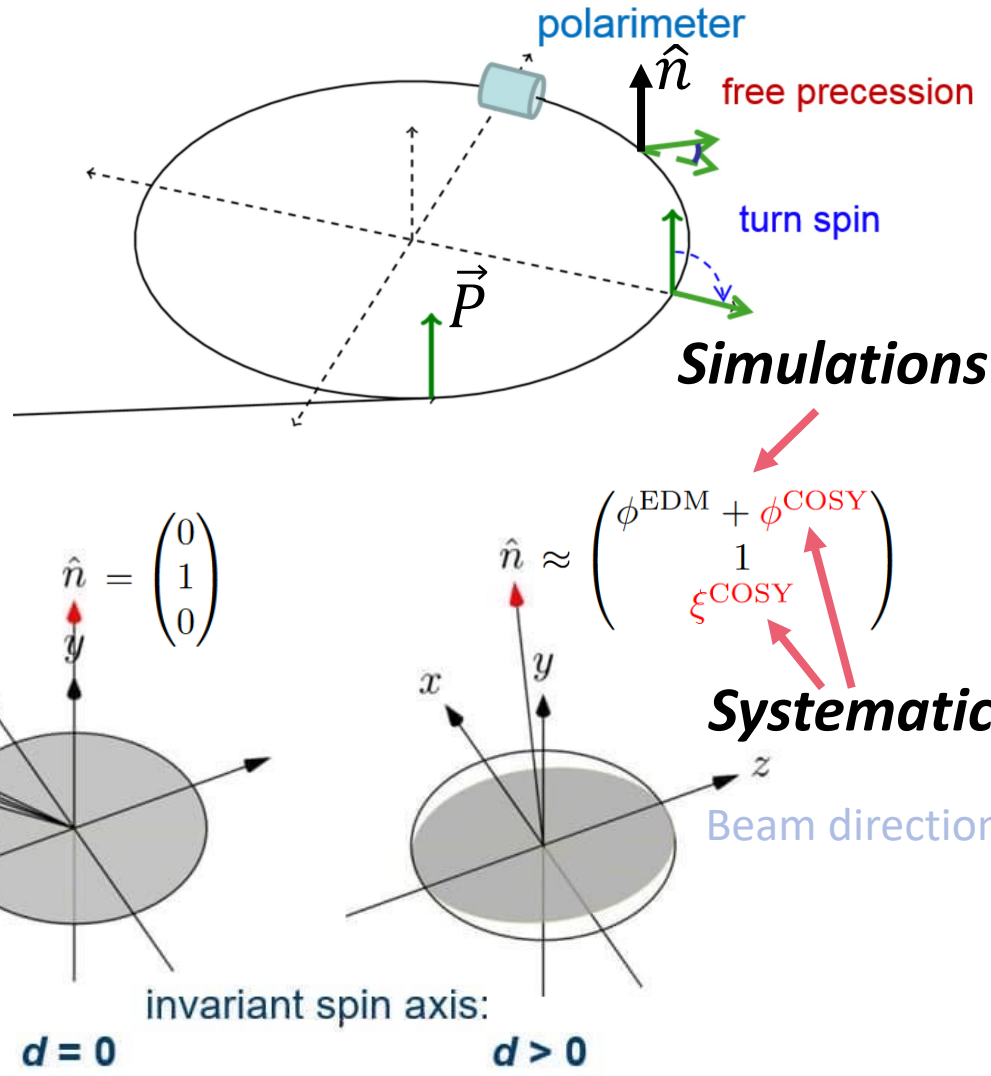
- **Goal**: Determination of the **orientation** of $\hat{n}$
- **Problem**: Ring **imperfections** (magnet misalignments,..) lead to rotations of $\hat{n}$ in **radial** (x) and **longitudinal** (z) direction



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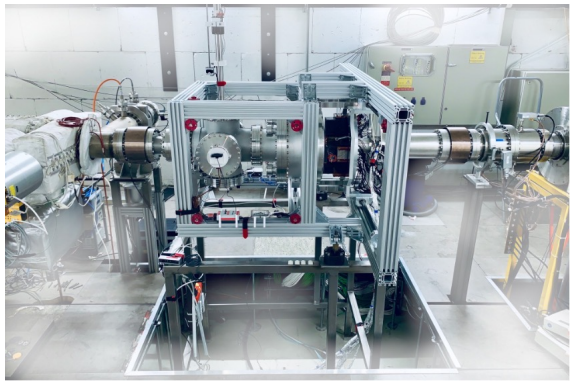
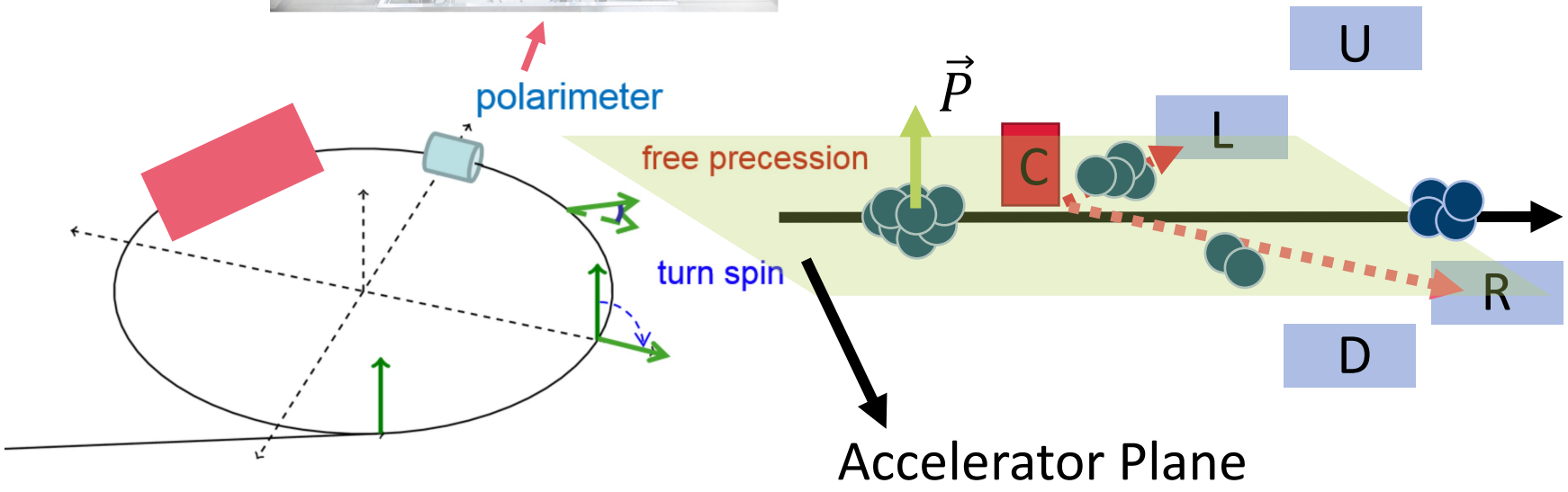
MEASUREMENT PRINCIPLE



$$p_y \propto \frac{N_L - N_R}{N_L + N_R}$$



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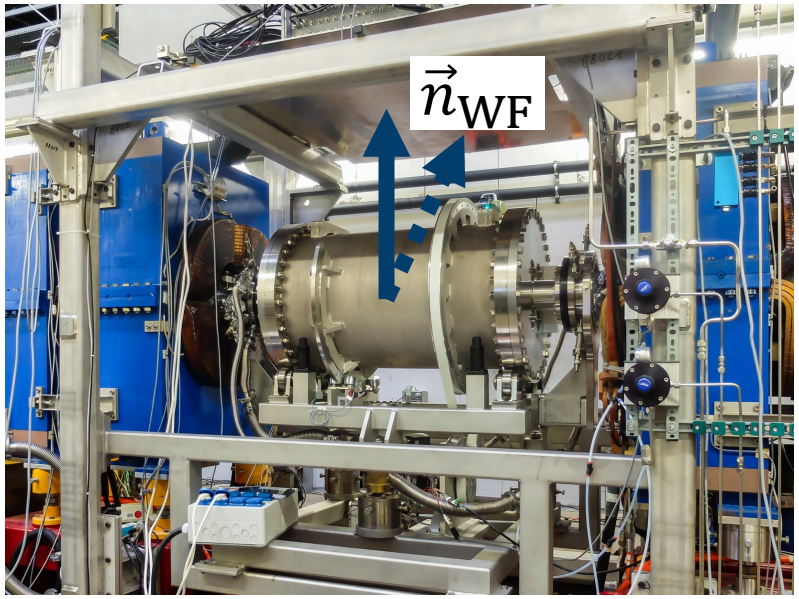

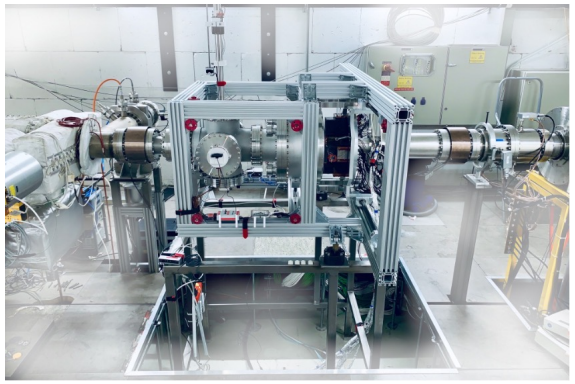

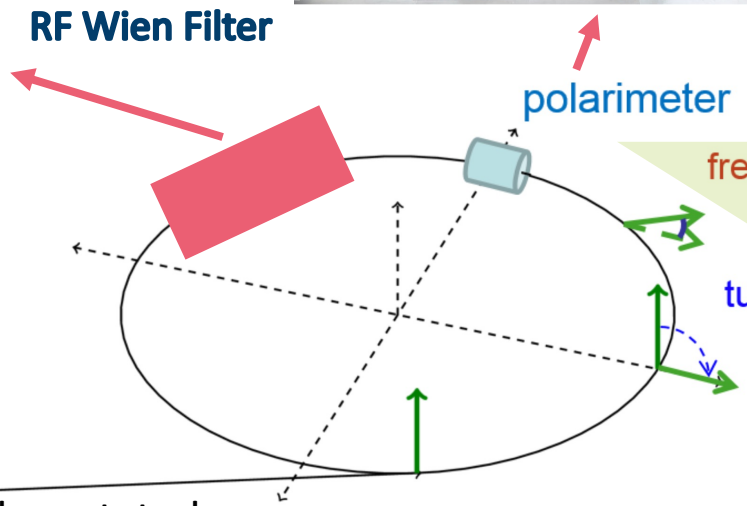

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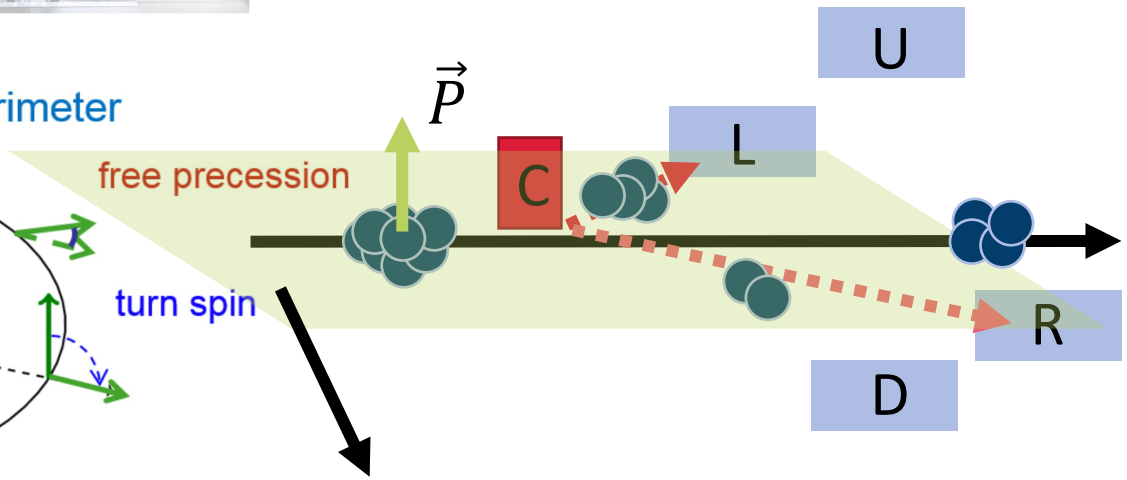
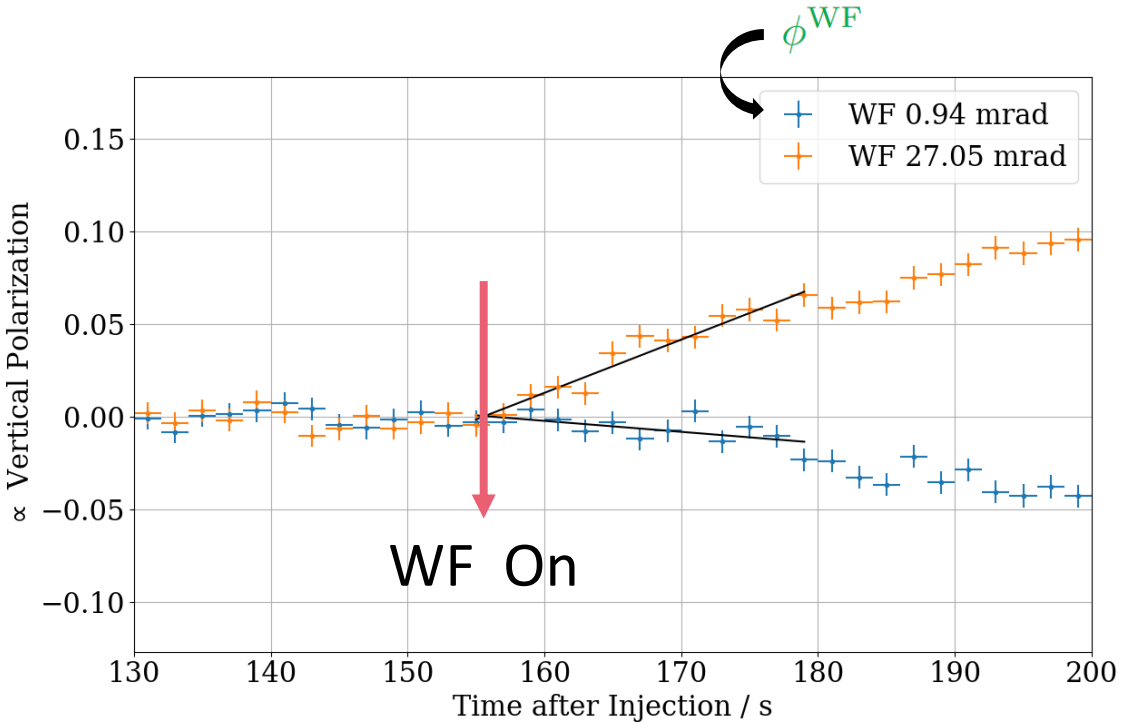
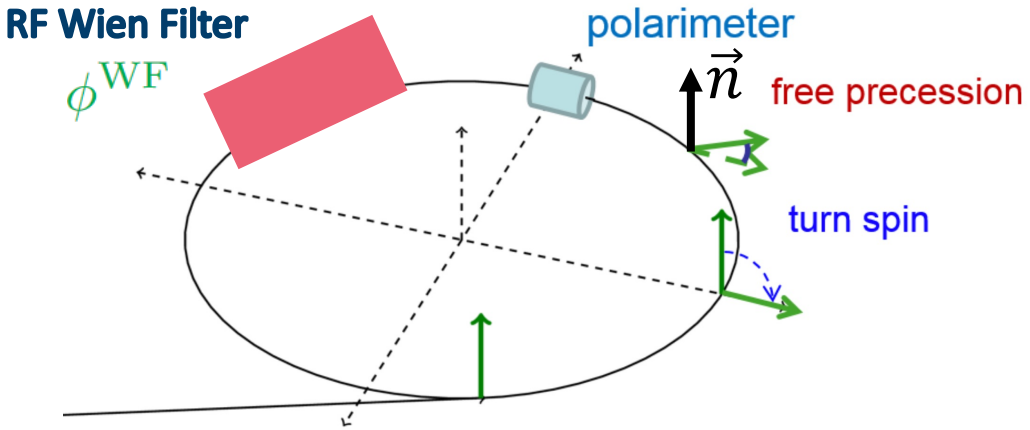


- $\vec{E} \perp \vec{B} \perp$ Beam $\rightarrow \vec{F}_L = 0$
- **Rotational** Device: $\vec{n}_{\mathrm{WF}}$- Field can be rotated around the beam pipe by $\boldsymbol{\phi}^{\mathbf{WF}}$

$$\vec{n}_{\mathrm{WF}} = \begin{pmatrix} \sin\left(\phi^{\mathrm{WF}}\right) \\ \cos\left(\phi^{\mathrm{WF}}\right) \\ 0 \end{pmatrix} \approx \begin{pmatrix} \phi^{\mathrm{WF}} \\ 1 \\ 0 \end{pmatrix}$$

MEASUREMENT PRINCIPLE





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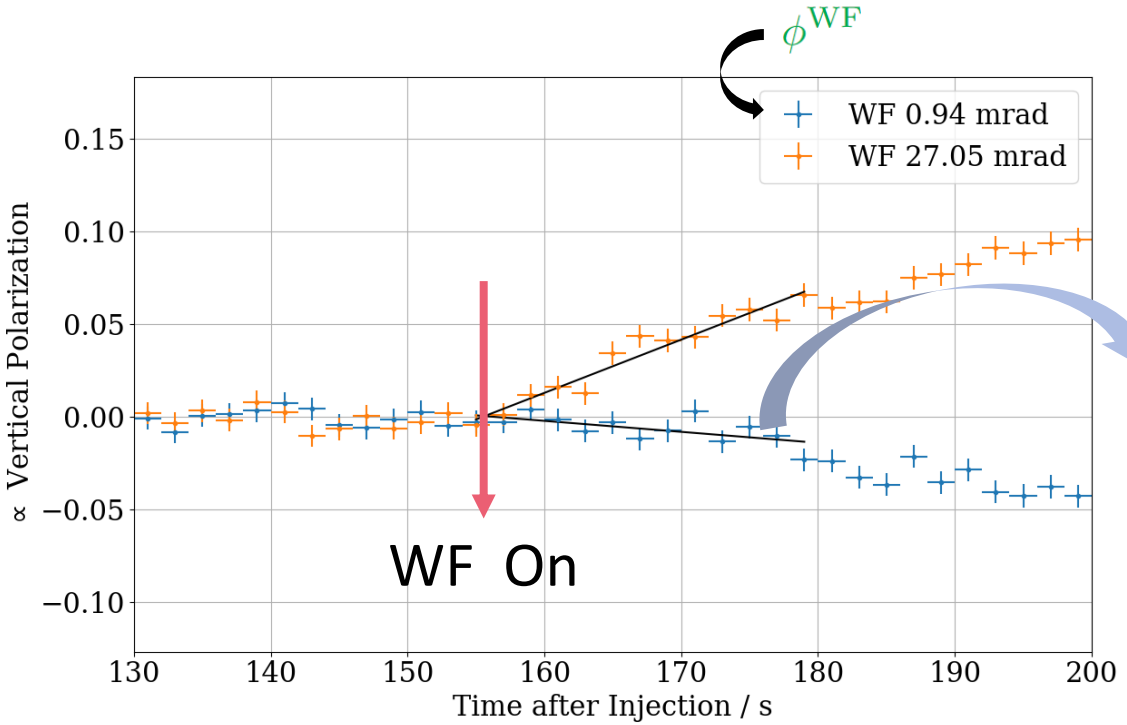
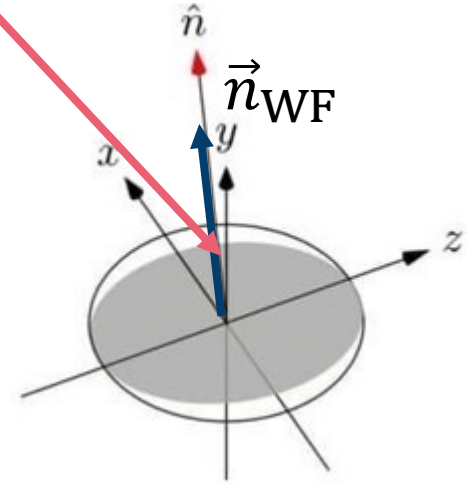
MEASUREMENT PRINCIPLE

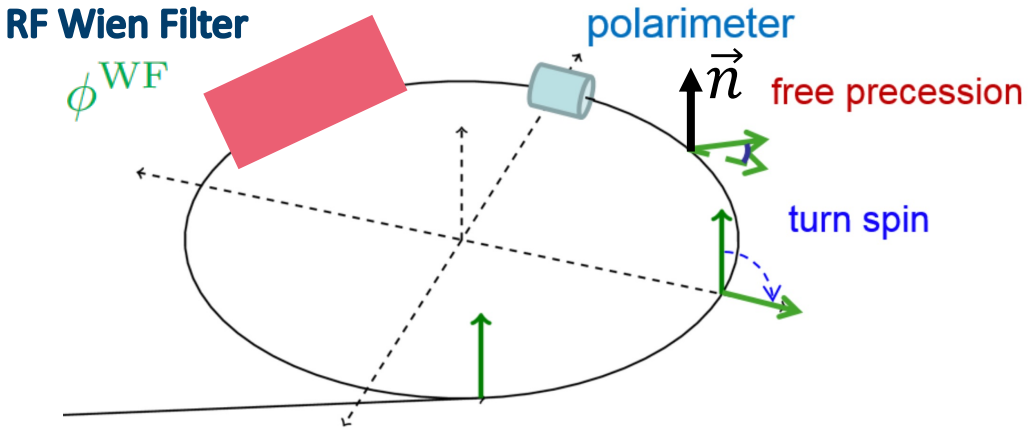


$$\epsilon^2\left(\phi^{\mathrm{WF}}\right) \propto |\vec{n}_{\mathrm{WF}} \times \vec{n}|^2 \quad \vec{n}_{\mathrm{WF}} : B \text{ field axis of rf Wien filter} \quad \vec{n} : \mathrm{ISA}$$
$$\propto A_1 \cdot \left(\left(\phi_0^{\mathrm{EDM}} + \phi_0^{\mathrm{COSY}}\right) - \phi^{\mathrm{WF}}\right)^2$$

Build up rate

$$\epsilon \propto \frac{\mathrm{d}}{\mathrm{d}t} p_y(t)$$





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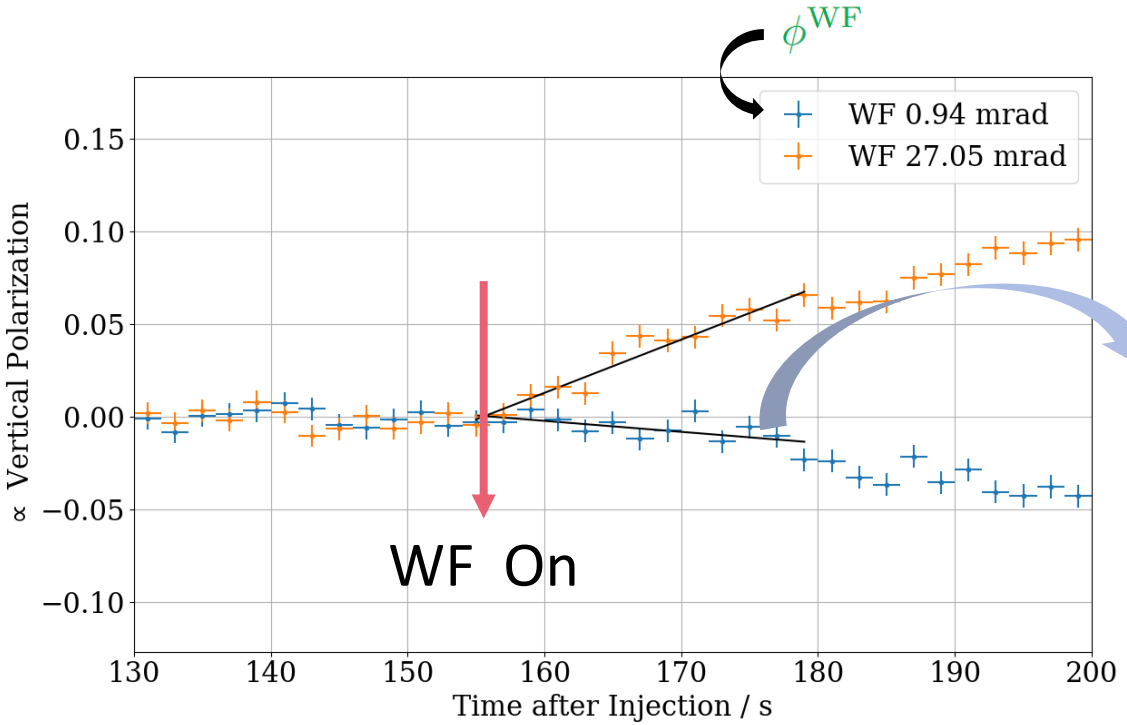

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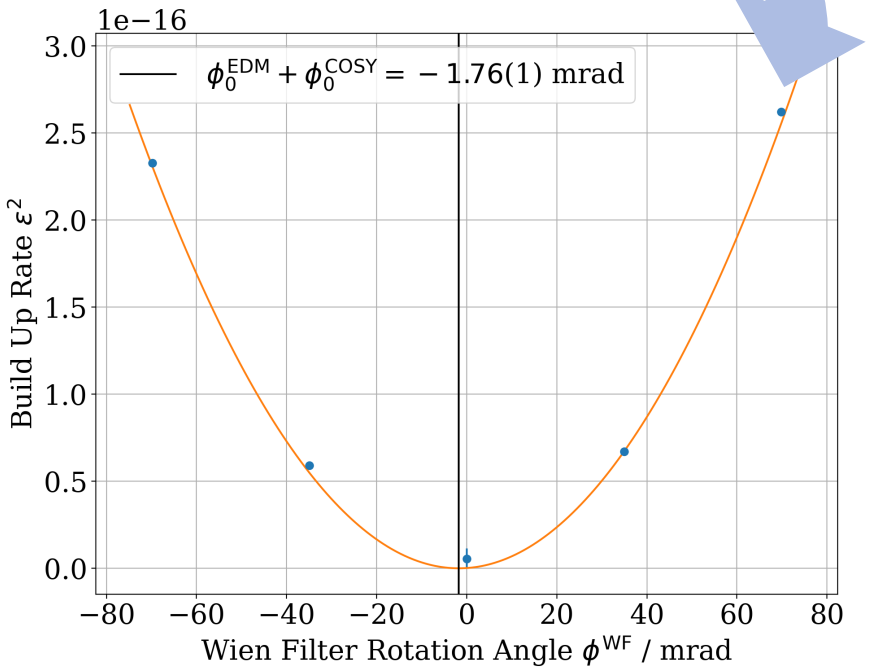

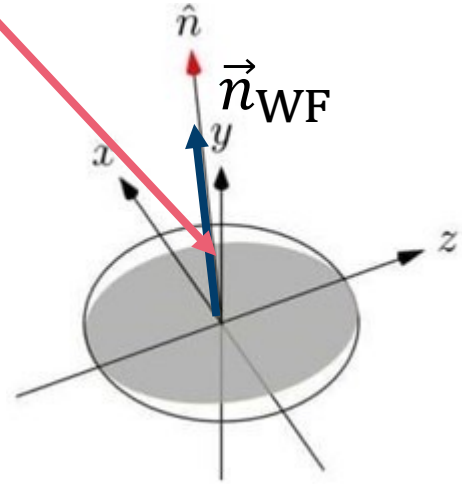

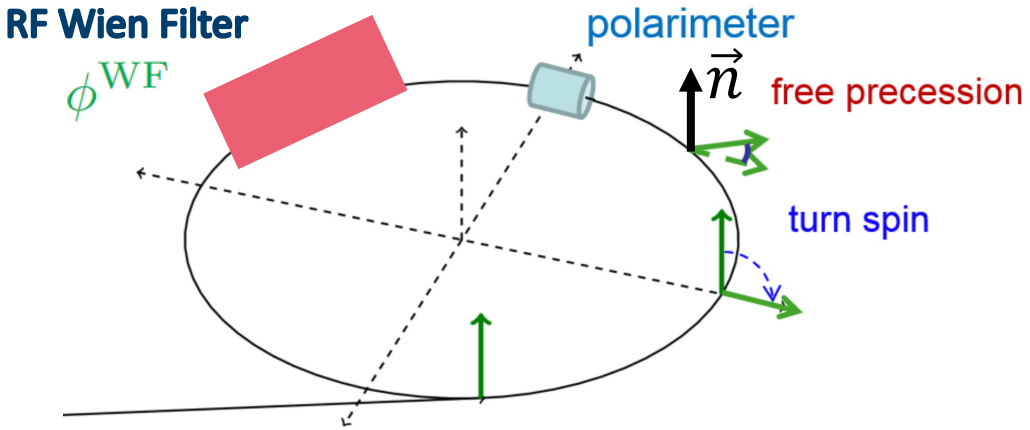

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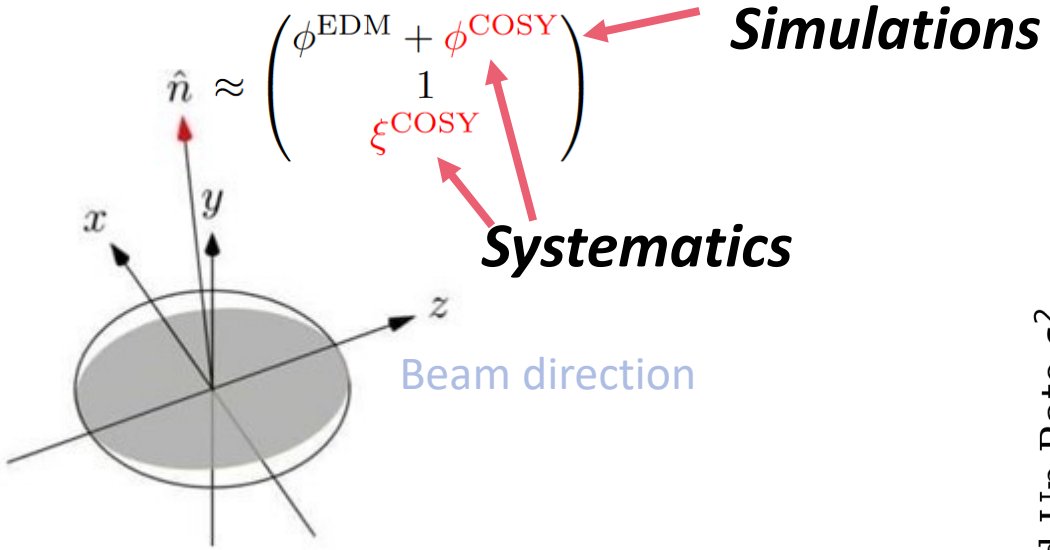
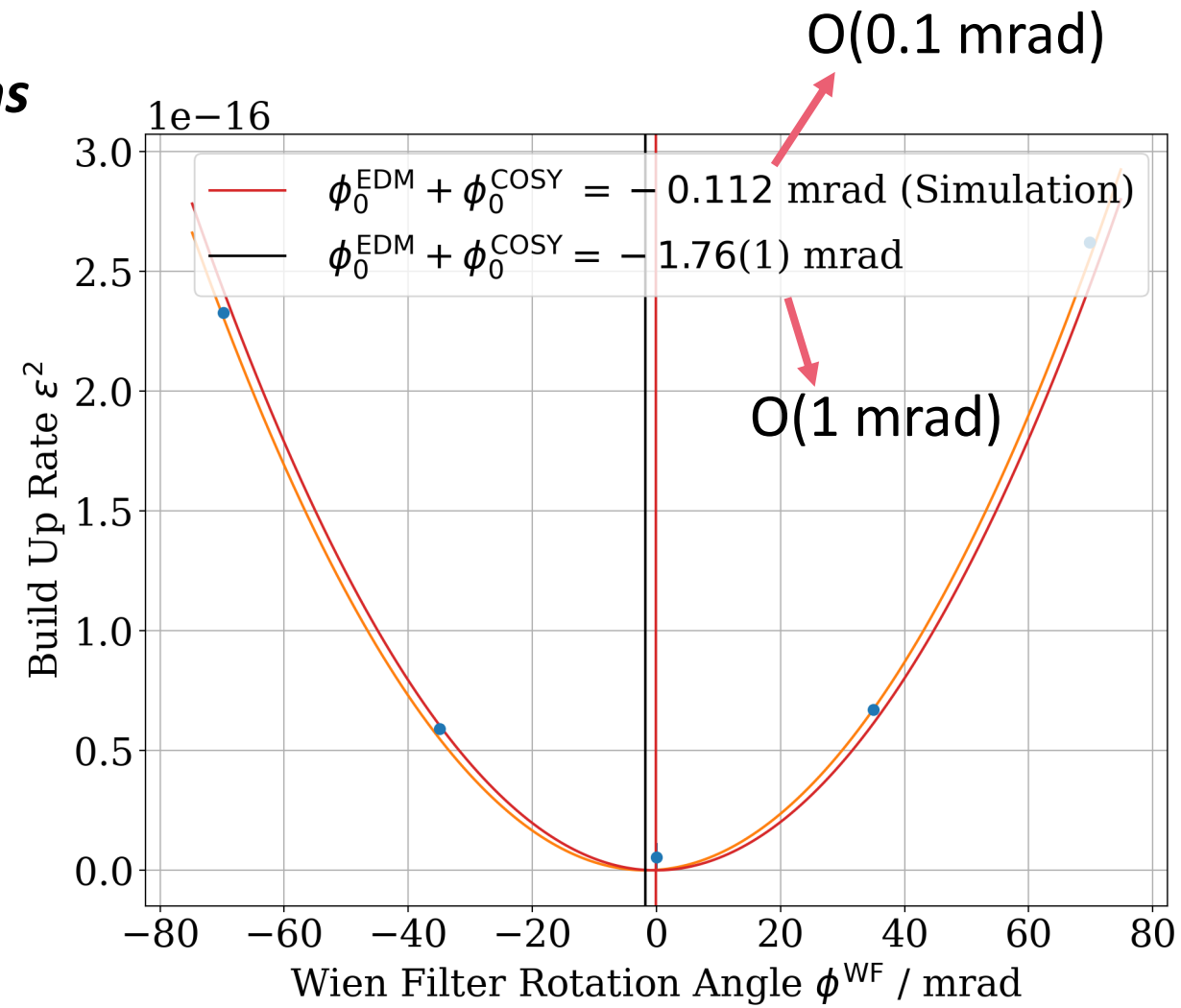
PRELIMINARY RESULTS

We are missing something!



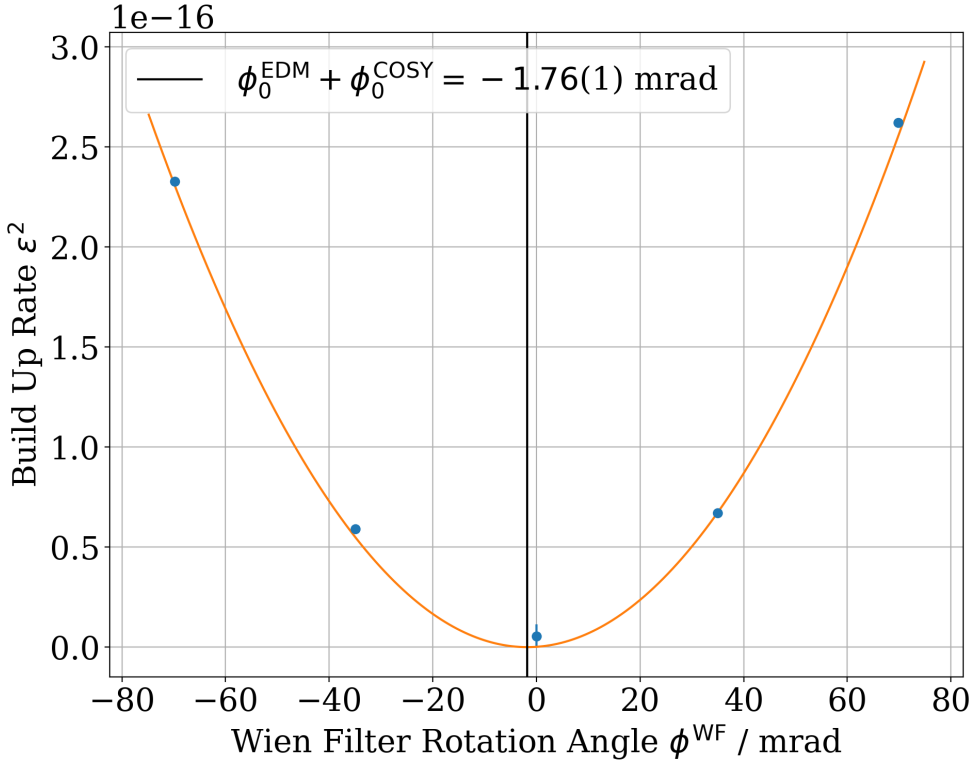


$1\ \mathrm{mrad} \approxeq 10^{-17} e \cdot \mathrm{cm}$

- Bmad **simulation** of the experiment (M. Vitz AKBP 9.2 16:00)
- Includes **current understanding** of (misaligned) magnets in COSY
- **Simulations predict** tilts of the invariant spin axis not larger than **O(0.1mrad)**
- Measured angles are an **order of magnitude too large**!
- Systematic studies will be used to **understand these angles**

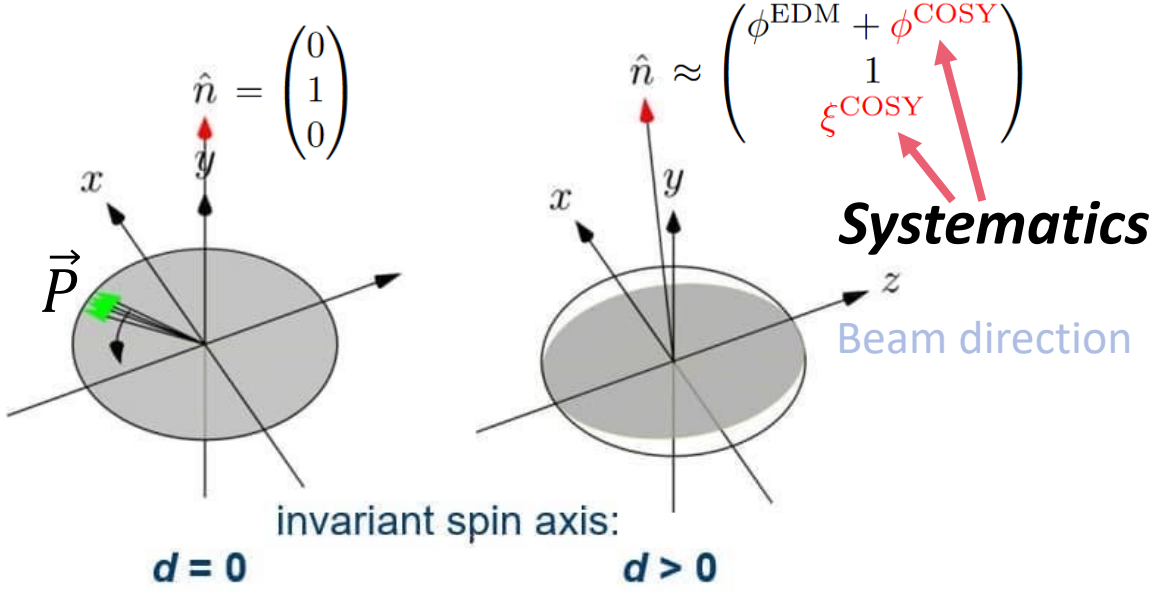
SUMMARY

- EDM as a source of **CP violation**
- Measure influence of EDM on **beam polarization**
- Orientation of **Invariant Spin axis** directly relates to **EDM strength**
- Order of magnitude is **too large**



Simulations

Systematics



	$\phi_0^{\mathrm{EDM}} + \phi_0^{\mathrm{COSY}}$
Experiment	$-1.76(1)$ mrad
Simulation	-0.112 mrad

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