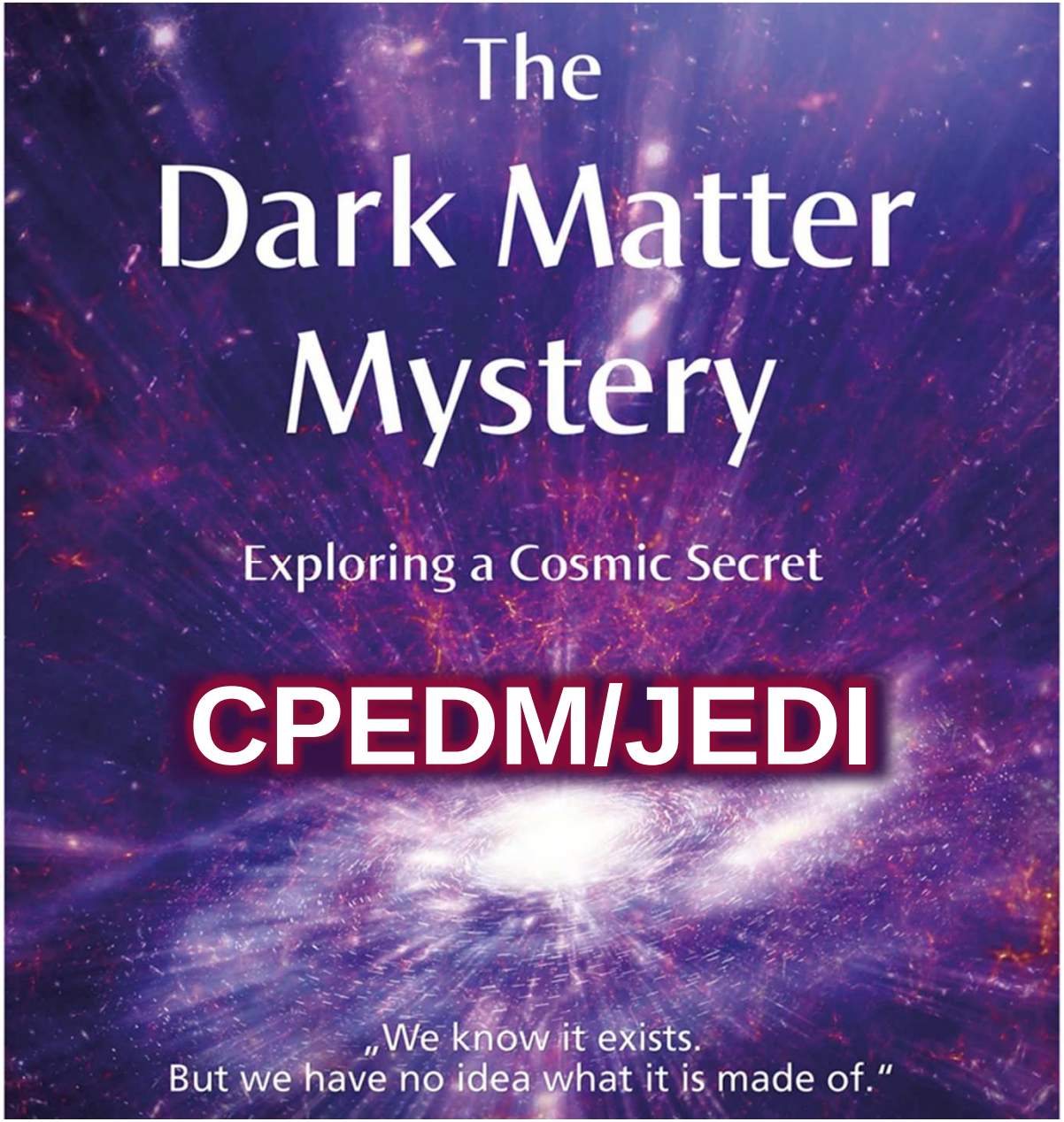


Credit: Planetarium Laupheim

DARK MATTER LAB

Sci. Kick-off Mtg.
Dec. 9, 2021

Hans Ströher

Prof. Univ. of Cologne,
FZ-Jülich, Germany;
Now: GSI Darmstadt

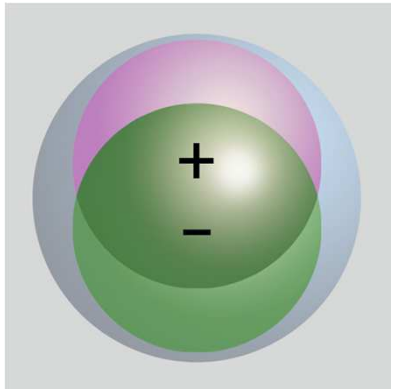
CPEDM …
Charged Particle
Electric Dipole Moment

JEDI …
Jülich Electric Dipole
Moment Investigations

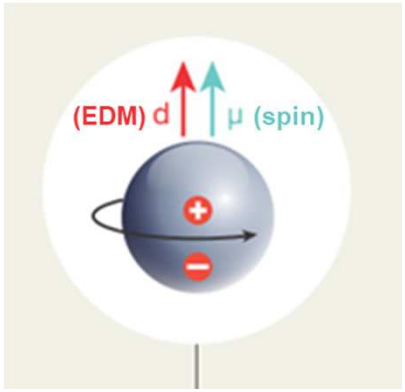
http://collaborations.fz-juelich.de/ikp/jedi/

ELECTRIC DIPOLE MOMENTS

- EDM: permanent separation of electric charges “+” and “-”



- EDM: vector parallel to spin



- EDMs of fundamental particles: ***P-*** and ***T-***violating → [CPT] → ***CP-V***

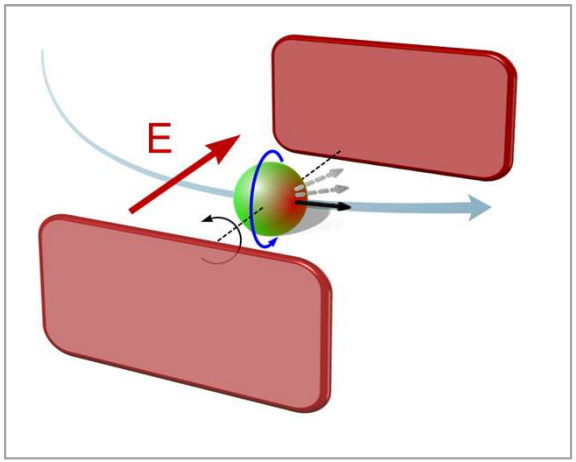
  - non-zero EDM: θ_{QCD} or BSM → need different systems to identify sources
  *- NO such EDM found yet – only (impressive) upper limits: **neutron**: $d_n \sim 10^{-26}$ e.cm*
  *- **JEDI/CPEDM**: charged particles*

EDM OF CHARGED PARTICLES (p, d)

- Basic method: observation of **particle spin** in external **E-field**

Torque on spin due to an EDM:
→ in-plane spin (slowly) rotates **out-of-plane**

$$\frac{d\vec{s}}{dt} \propto \underbrace{d(\vec{E} + \vec{v} \times \vec{B})}_{=\vec{\Omega}_{EDM}} \times \vec{s}$$



Charged particles **accelerated** in **E-field**: confine movement with a „trap“

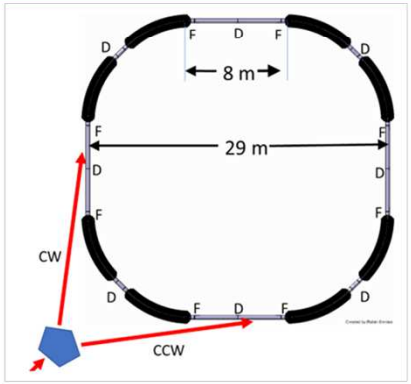
→ *in practice: polarized beam in a storage ring; **polarimeter** to observe vertical build-up*

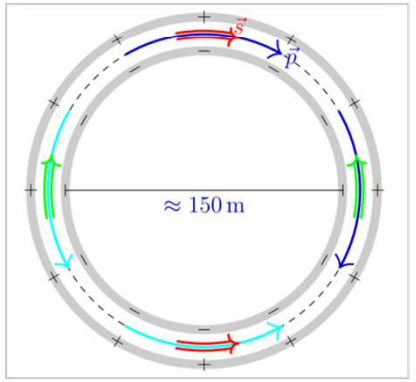
Problem: particles w/ spin have **magnetic dipole moment: MDM** >> EDM
→ *must get rid of/reduce MDM effects: e.g. **all-electric** ring, **frozen spin**, **CW/CCW** …*

JEDI AND CPEDM

- Presently: only a **magnetic storage ring**: **COSY** (at IKP of FZJ)

1	2	3
Precursor Experiment	**Prototype Ring**	**All-electric Ring**
dEDM proof-of-capability (orbit and polarization control; first dEDM measurement)	**pEDM proof-of-principle** (key technologies, first direct pEDM measurement)	**pEDM precision experiment** (sensitivity goal: 10^{-29} e cm) → **a big challenge!**

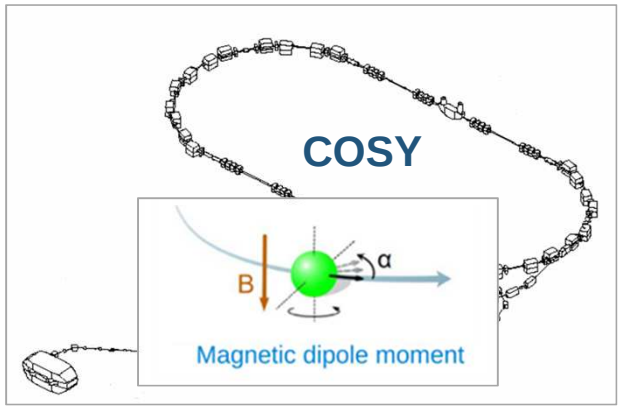


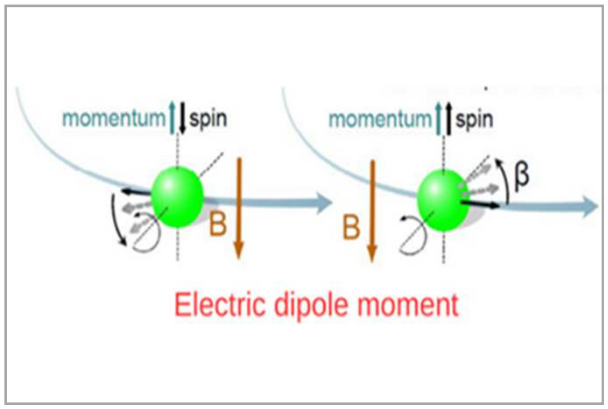


→ **Staged approach:** precursor … prototype … final precision EDM ring

COSY MEASUREMENTS (I): *STATIC* EDM

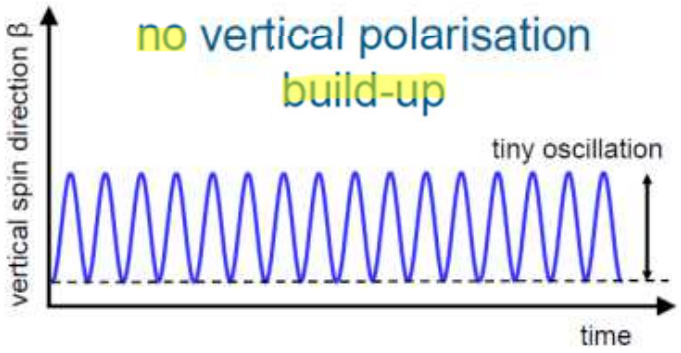
- **Spin precession** ("(g-2)") of polarized particle beam due to MDM:





Torque on spin **changes sign** every half period of the MDM precession → cancellation

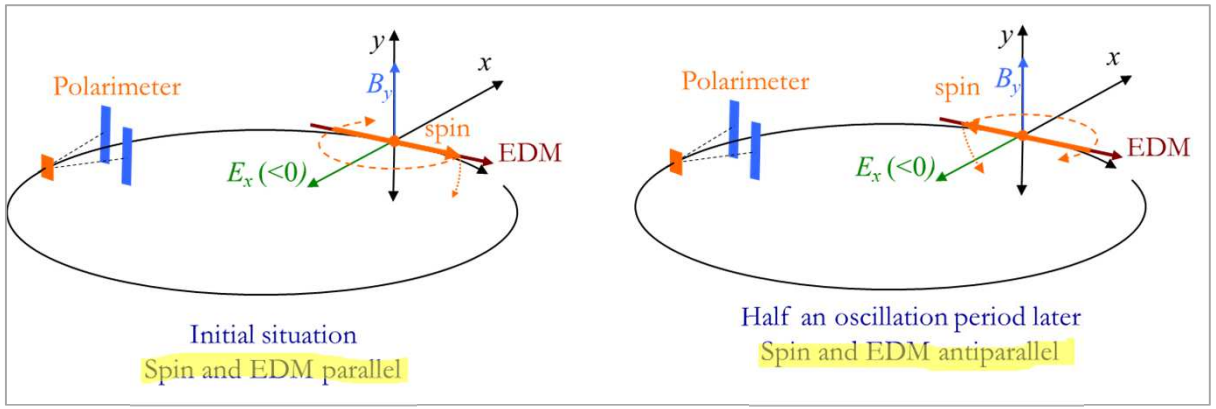
→ Expectation:



(possibility to search for EDM in COSY w/ "RF-Wien filter" – with reduced sensitivity)

COSY MEASUREMENTS (II): *OSCILLATING* EDM

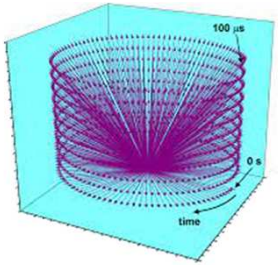
- Possible **resonance condition**: (g-2)-precession = "*AC*-EDM oscillation"



$$d = d_{DC} + d_{AC}\sin(\omega_a t + \varphi_a)$$

$$\omega_a = \frac{m_a c^2}{\hbar}$$

Torque on spin:
constructive
→ build-up



Use to **search for axions/ALP** (**DM** candidates): coupling to **g (N)** →

Oscillating EDM; search in a **magnetic storage ring**: polarization jump

temporal change of Ω_{MDM} → mass scan
phase unknown – use of (4) multiple bunches with different polarization directions
proof-of-principle measurement at COSY

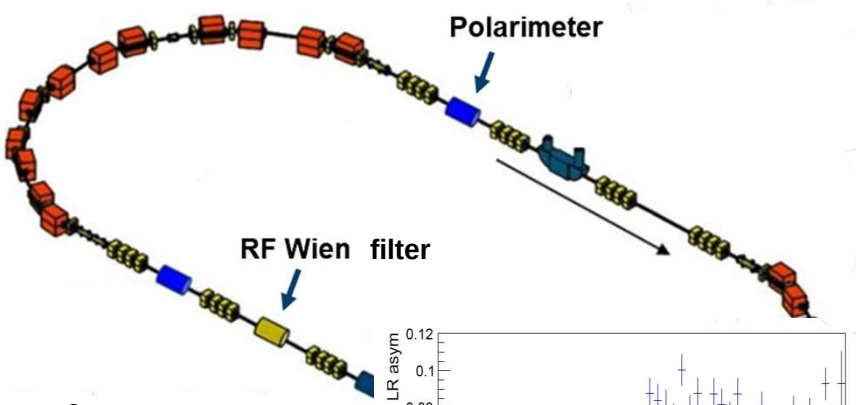
COSY MEASUREMENTS (III): SEARCH (DEUTERON BEAM)

- Proof-of-principle **oEDM-search at COSY**:

Use (horizontally) **polarized** (and electron-cooled) **deuteron beam**, momentum 0.97 GeV/c

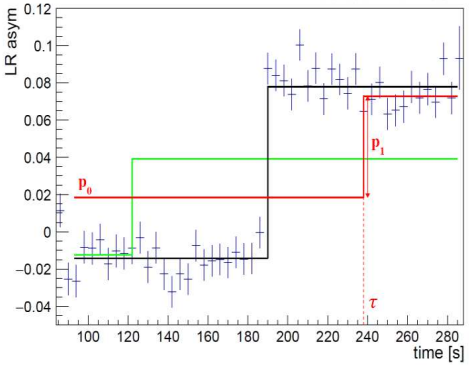
4 beam bunches simultaneously (different directions of the polarization)

Polarimeter monitors polarization



Vary **frequency –** search for a resonance (**polarization jump**)

Test w/ artificial polarization jump by RF Wien filter



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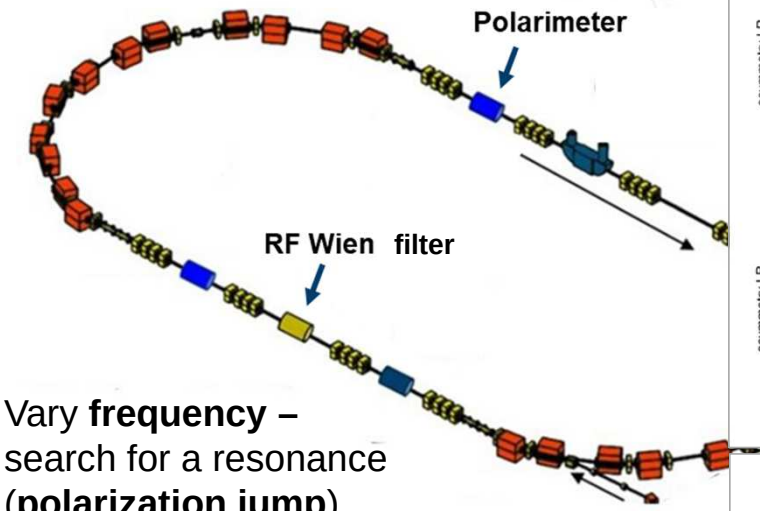

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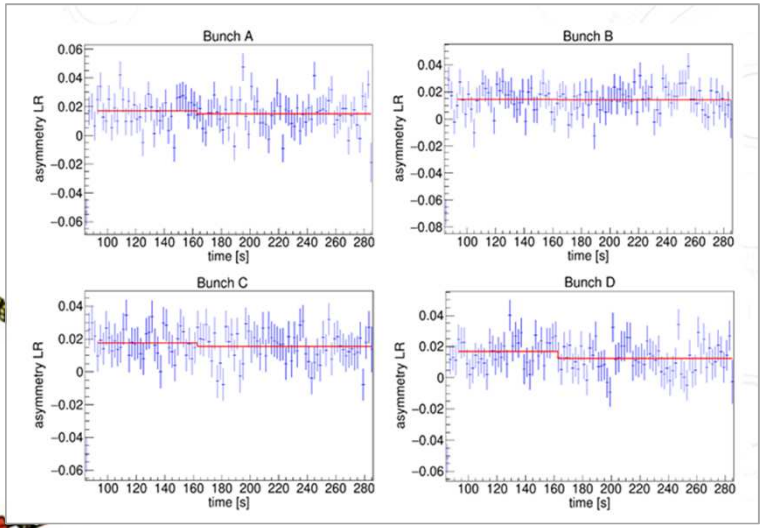


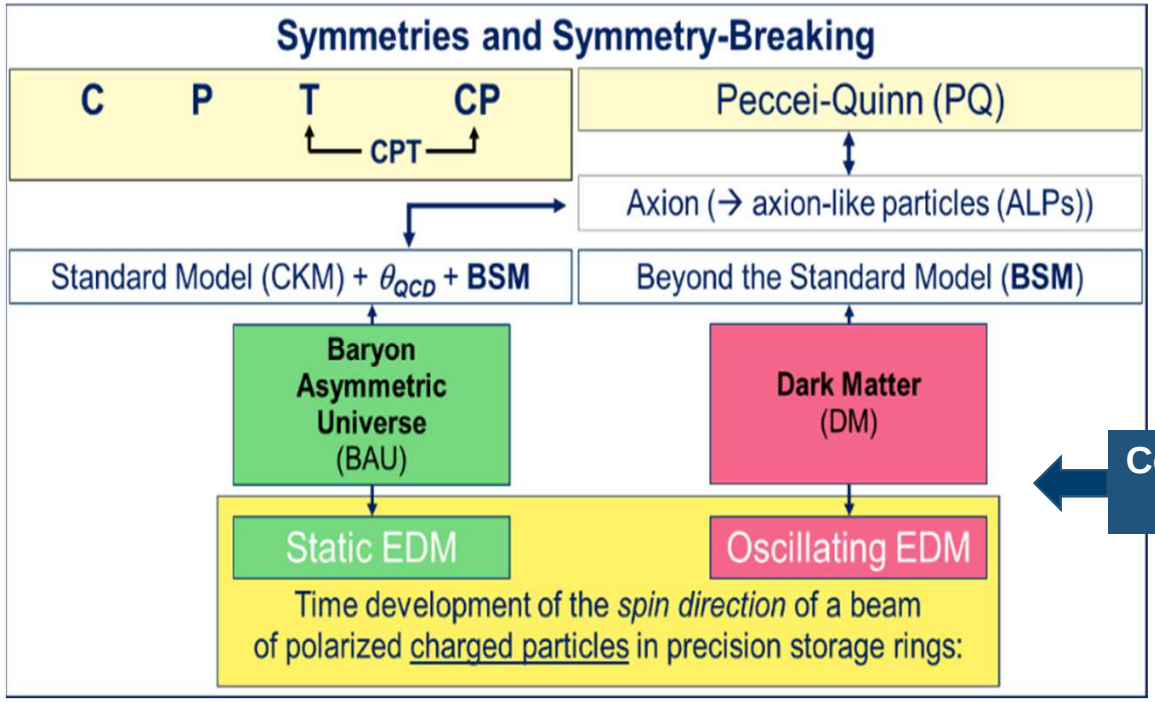
About 100 scans done:

Frequency range: 1.5 kHz around 120 kHz
Mass range: (4.96 – 5.02) x 10^{-9} eV

Scan result: **no signal observed**

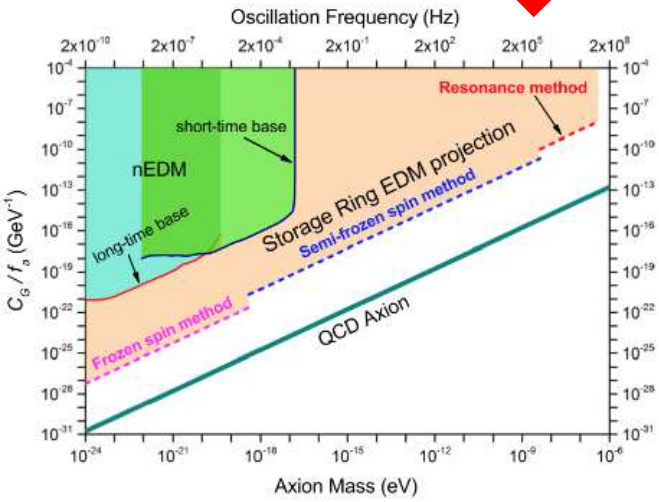
→ **Method works**! → exclusion limit (expect ~10^{-22} e.cm)

SUMMARY, CONCLUSION



Coupling to gluons

COSY



Besides static EDMs, **oscillating EDMs** (to search for axion/ALP DM) provide an additional scientific case for CPEDM

WHAT *DMLab* CAN DO

- **Coordination** of different DM searches
- **Support** to realize project in Europe