

EDM: Bright Future for COSY







September 6, 2013 | Andreas Lehrach

Our World consist of Matter



ANTI-MATTER!

... and not Antimatter

Antimatter on Earth can be produced or observed

- in particles physics experiments
- in (secondary) cosmic radiation
- and in cosmic rays

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Big Bang

Prevailing cosmological model that describes the early development of our Universe

Equal amounts of Matter – Antimatter was produced

Where the antimatter went is still not clear today

Violation of fundamental symmetries needed to explain the disappearance of Antimatter Sakharov (1967)



The mystery of the missing antimatter (the puzzle of our existence)



Search for Antimatter





Did the Antimatter really disappear ?

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Electric Dipole Moment: What is it?

Definition





Charge separation creates an electric dipole

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Electric Dipole Moment: What is it?



p = q s

ÜLICH

Water molecule: permanent electric dipole (has degenerate GS w/ different parity)

p ~ 3 · 10⁻³⁰ C m ~ 2 · 10⁻⁹ e cm

Charge separation creates an electric dipole

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Example:

 H_2O

Symmetry of Electric Dipole Moments





IF particle has an EDM

Violation of discrete symmetries (P and T)

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Neutron Electric Dipole Moment





No EDM yet, only limits

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Electric Dipole Moment





EDM: precision frontier

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Limits for Electric Dipole Moments



EDM searches - only upper limits up to now (in e.cm):

Particle/Atom	Current EDM Limit	Future Goal
Neutron	< 3 ×10 ⁻²⁶	~10 ⁻²⁸
¹⁹⁹ Hg	< 3.1 ×10 ⁻²⁹	~10 ⁻²⁹
¹²⁹ Xe	< 6 ×10 ⁻²⁷	~10 ⁻³⁰ – 10 ⁻³³
Proton	< 7.9 ×10 ⁻²⁵	~10 ⁻²⁹
Deuteron	?	~10 ⁻²⁹

CP violation can have different sources

It is important to measure neutron **and proton and deuteron**, and light nuclei EDMs in order to disentangle various sources of CP violation

No direct EDM measurement of charged particles

EDMs – Ongoing / planned Searches





P. Harris, K. Kirch ... A huge worldwide effort

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How EDMs are Measured





Spin vectors of particles a rotating

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How EDMs are Measured





"Freeze" horizontal spin

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Storage Ring EDM Project





92 members

(Aachen, Dubna, Ferrara, Cornell, Jülich, Krakow, Michigan, St. Petersburg, Minsk, Novosibirsk, Stockholm, Tbilisi, ...) 10 PhD students

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Options:

All-electric ring (proton, electron): only E-field All-in-one ring (proton, deuteron, ³He): E- and B-fields



srEDM Collaboration (BNL) - JEDI Collaboration (FZJ)

Dedicated precision storage ring

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Cooler Synchrotron COSY





COSY: From tests to first direct measurement

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R&D Activity	Goal	Test
Internal Polarimeter	spin as a function of time	COSY
	Systematic errors < 1 ppm	
	Full-scale polarimeter	COSY
Spin Coherence Time	SCT >10 ³ s	COSY
Systematic effects	Estimate for systematic limits	COSY
Beam Position Monitor	resolution 10 nm,1 Hz BW 64 BPMs, 10^7 s measurement time \rightarrow 1 pm (stat.) relative position (CW-CCW)	RHIC IP
E/B-field Deflector	17 MV/m, 2 cm plate separation, 0.15-0.5T	FAME

JEDI – First Direct Measurement





Establish srEDM, first direct measurement ; sensitivity ~10⁻²⁴ e

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