Electron EDM Experiment using Francium at TRIUMF

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CAP Congress

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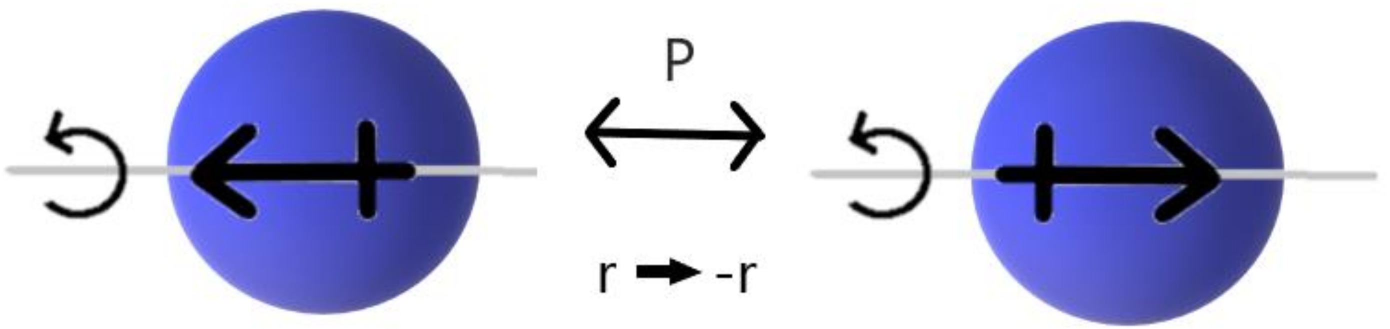
Outline

- EDM searches
- Atomic fountain experiment
- Finer experimental details

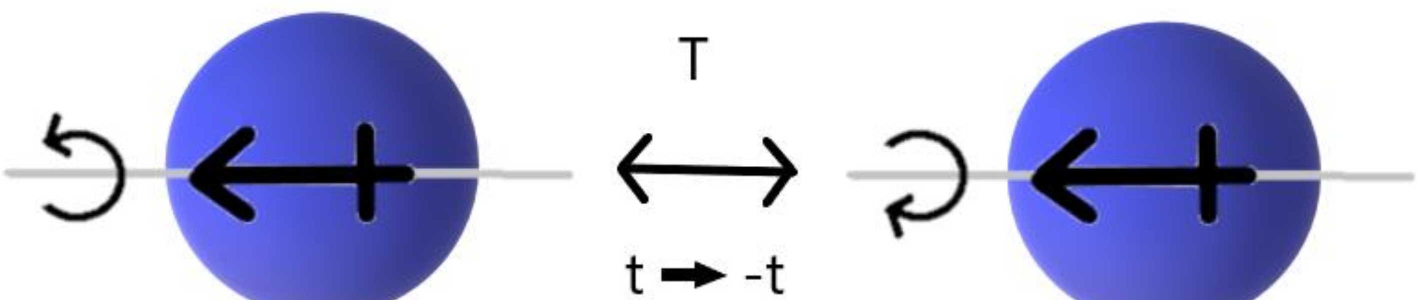
Electric Dipole Moment Searches

EDM?

- Intrinsic separation of charge
- Violates P-symmetry



- Violates T-symmetry
  - Equivalent to CP-violation



CP violation in Standard Model

- CP violation observed in electroweak interaction
  - None in QCD, not large enough to explain baryon asymmetry

- In Standard Model: $d_e < 10^{-38}$ e cm $d_n < 10^{-32}$ e cm

- eEDM limits:

$d_e \leq 1.3 \times 10^{-28}$ e cm	HfF^+	2017
$d_e \leq 1.3 \times 10^{-29}$ e cm	ThO	2014
$d_e \leq 1.3 \times 10^{-27}$ e cm	Tl-205	2002

- Experiments search for EDMs as any observation is new source of CP violation $\rightarrow$ new physics!
  - Results complementary to high energy colliders

eEDM in francium

- eEDM search in alkali atoms look for energy difference in valence electron aligned v. anti-aligned with applied E-field
  - Or as a phase difference between superposition of states

- Alkali atoms: simple atomic physics

- Relativistic enhancement: Rb: 25 Cs: 118.5 Fr: 903

- Apparatus first built using Cs at LBNL, to learn better control of systematics

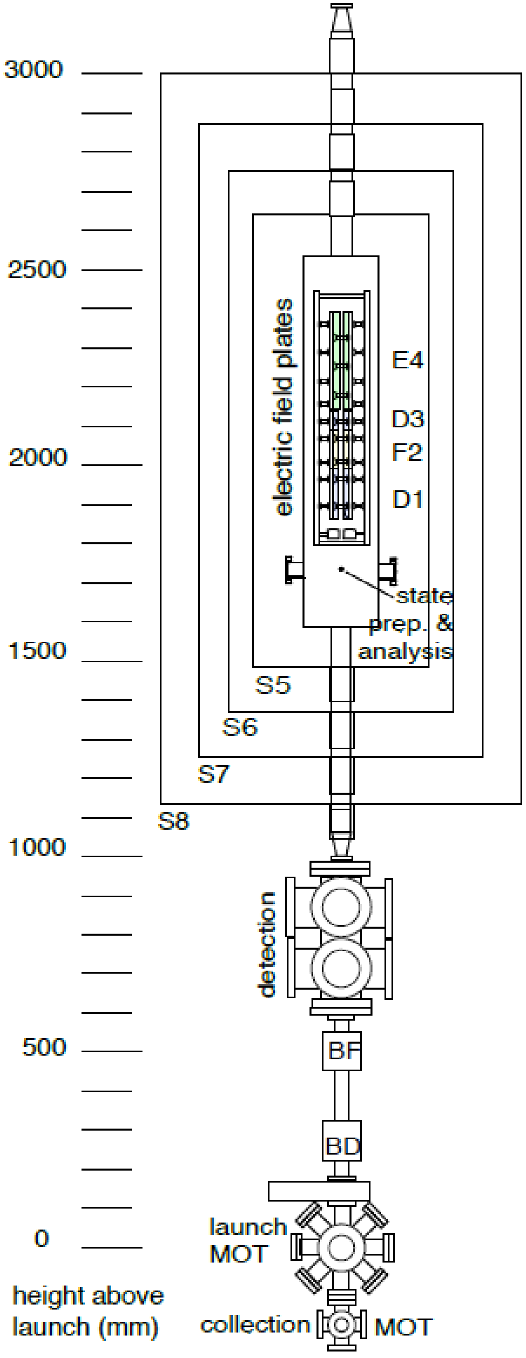
- Relocation to TRIUMF for Fr: goal: $d_e \leq 8 \times 10^{-30}$ e cm

Atomic Fountain Experiment

Francium atomic fountain

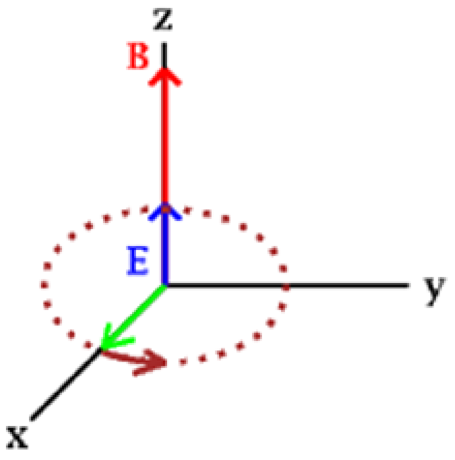
- Two magneto-optical traps
  - Collection of Fr from beam
  - Launch MOT
- Launch atoms: measurement in freefall, free space
- Magnetic shielding, electric field plates
- Optical state preparation, analysis, and detection
- Proof-of-principle

PRA 75, 063416 (2007)

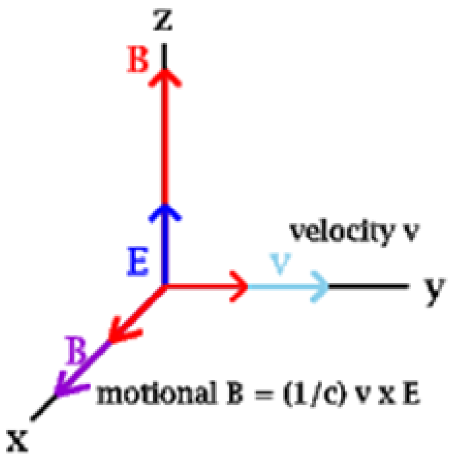


Why a fountain?

- Atoms precess in E,B fields



- EDM signal: odd in reversal of E
- Motional magnetic field effect (**v** x **E**)
  - Odd in reversal of E, mimics EDM



- Fountain: Velocity reverses under gravity
  - Suppress motional systematic
  - Atoms slow: **E** quantization
- Systematics are the limiting error in EDM experiments

eEDM Experimental Details

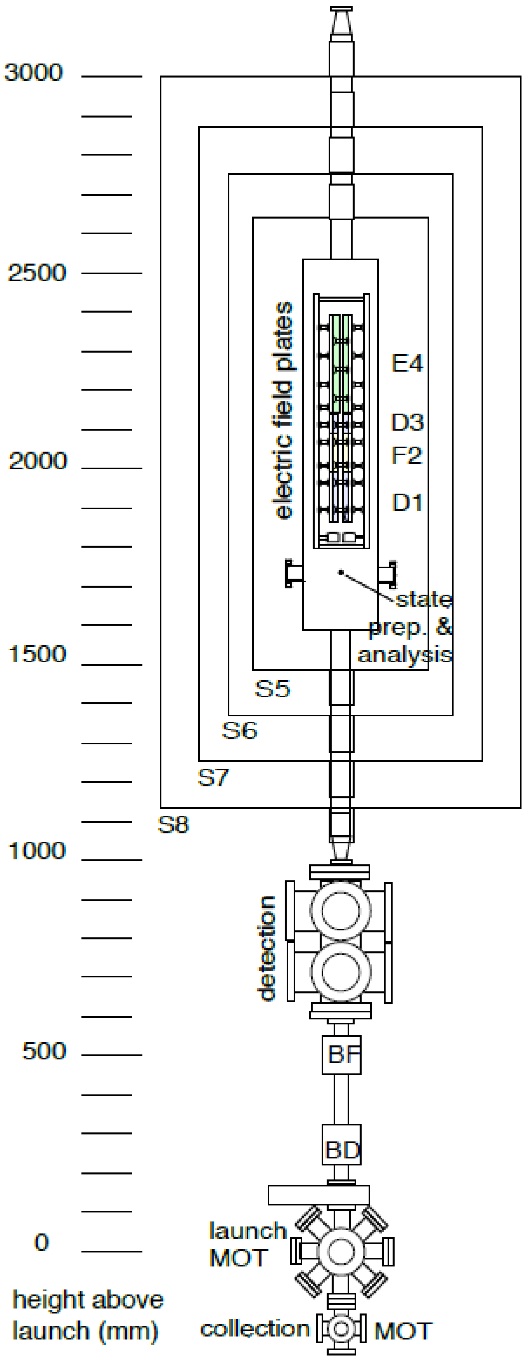
Atom transport

- Launch by detuning vertical beams
  2.44 m ⟶ 6.8 m/s

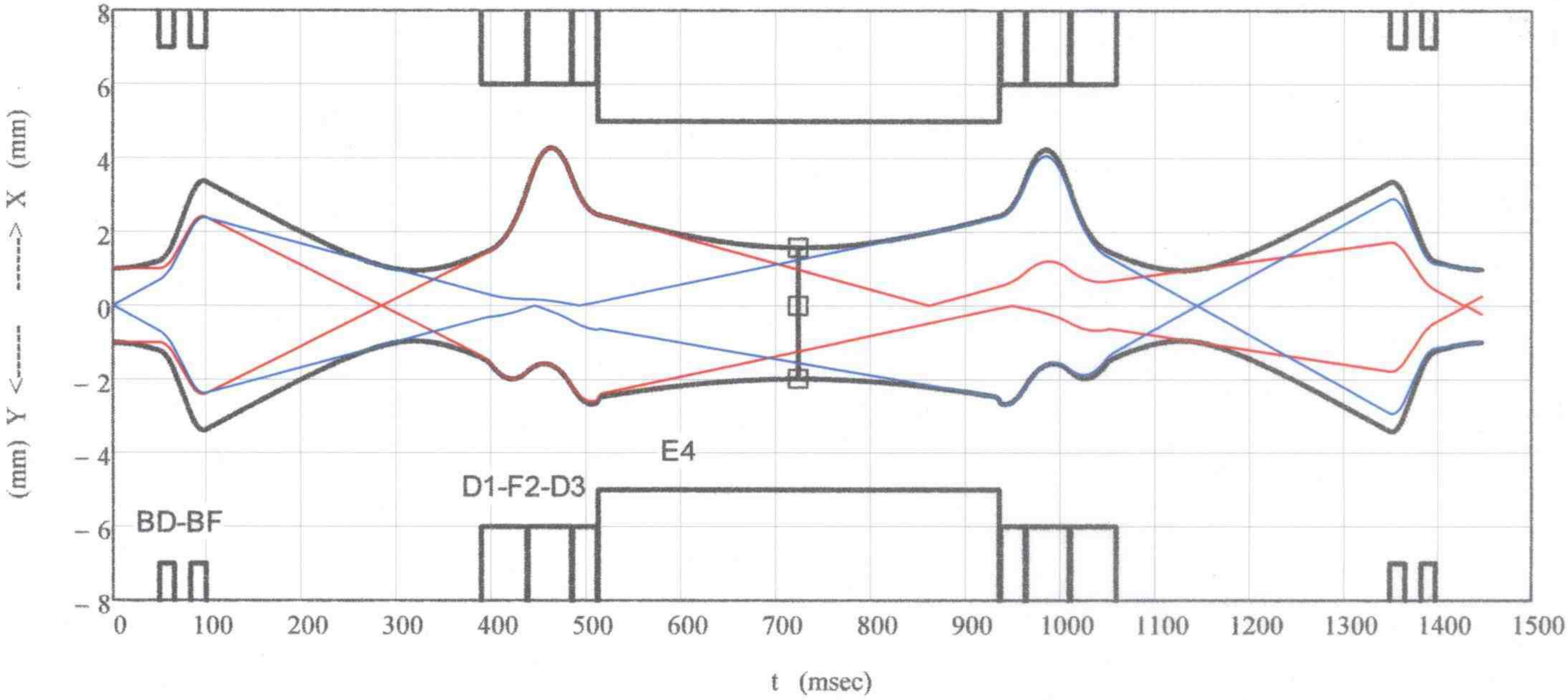
- Magnetic sextupoles BF/BD
  - Focus/defocus to counter expansion

- Shaped field plates
  - Counter strong-field seeking atoms

- ~75% return to be re-trapped
  - Great for limited Fr



Atom transport



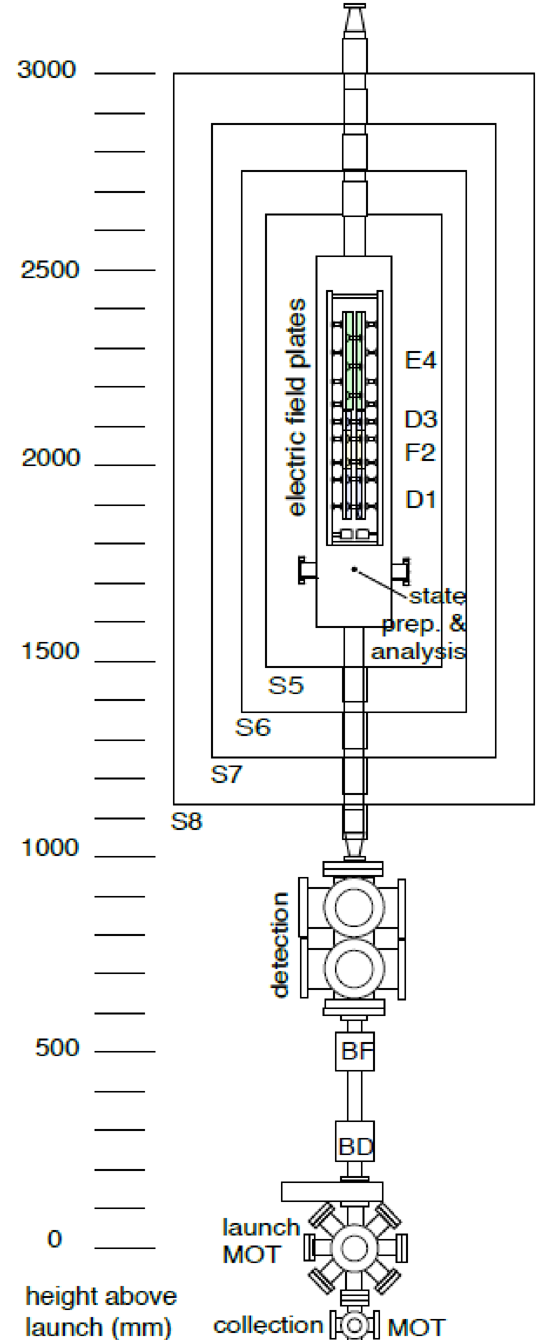
BD/BF: magnetic sextupoles

D1/F2/D3: Shaped field plates

X/Y: Parallel/Perpendicular to field plates

Magnetic shielding

- Need magnetic shielding factor 10^7
  - 4 nested shells
- Lots of tricky aspects
- See poster



eEDM Research Collaboration

LBNL

Robert Collister, Ben Feinberg, Harvey Gould, Yan Li, Charles Munger Jr., Hiroshi Nishimura, Chris Timossi

TRIUMF

John Behr, Matthew Pearson

Missouri S&T

Ulrich Jentschura

… and you?

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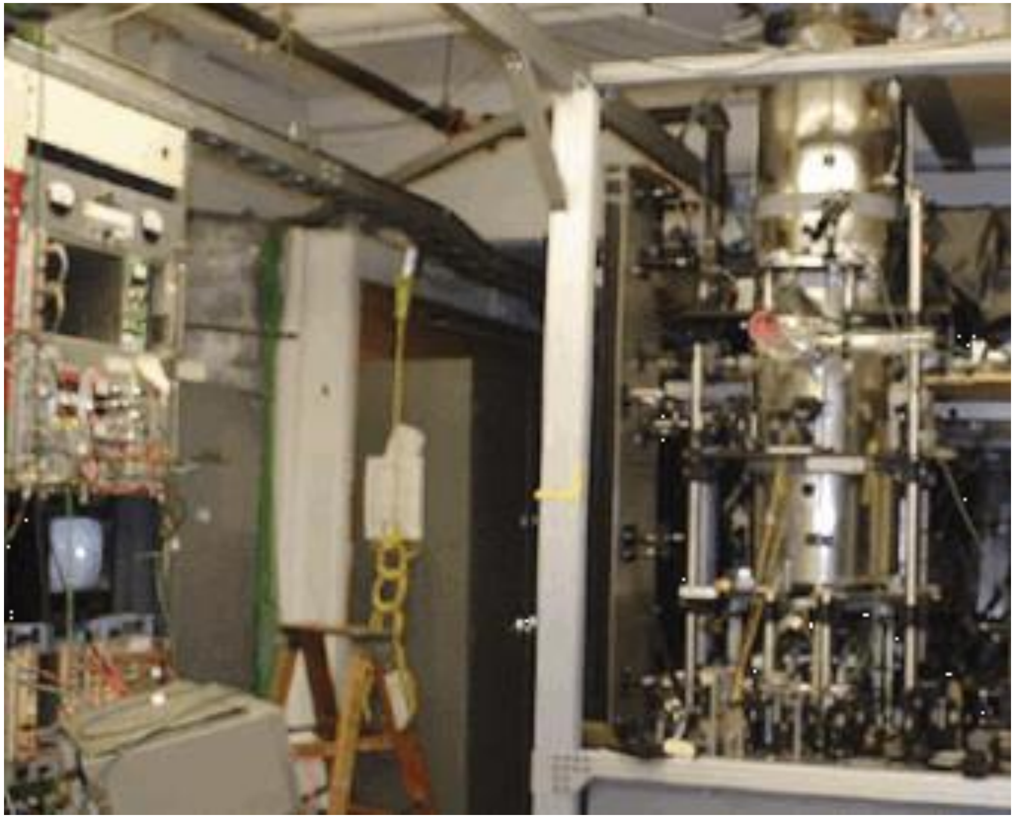
Bonus content

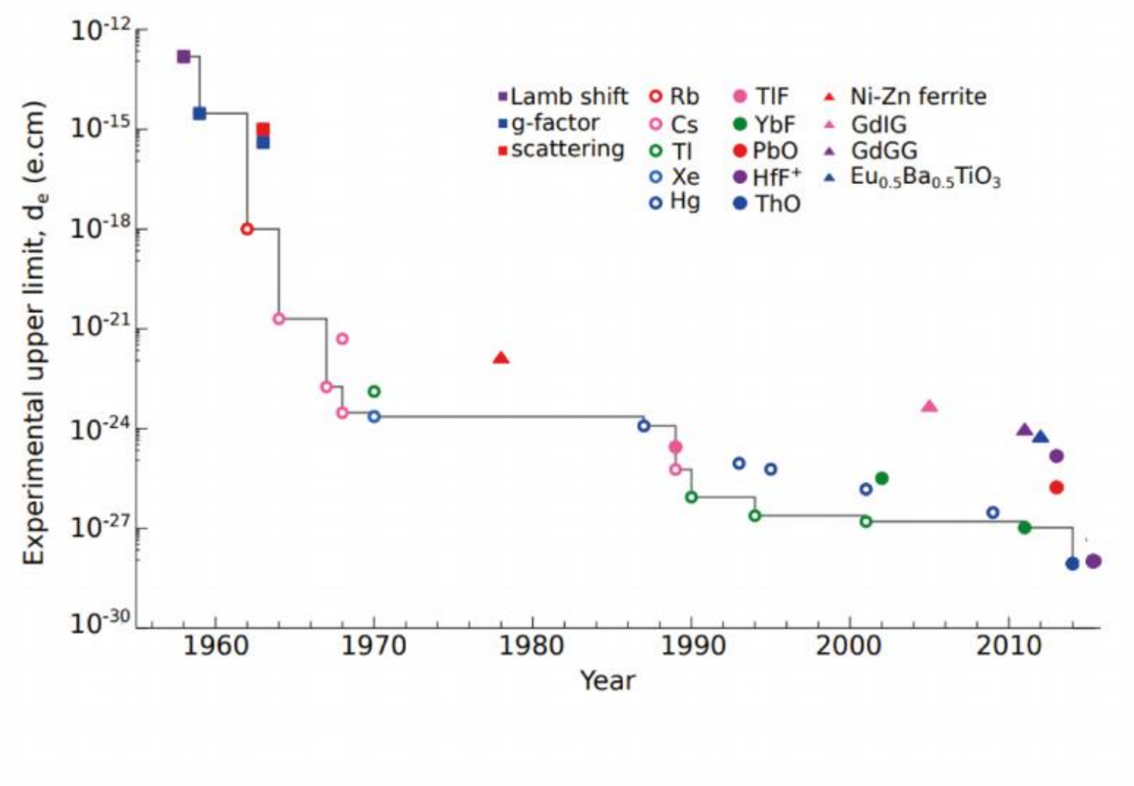
Proof-of-principle Cs fountain

- Demonstrated:
  - Launching Cs
  - State preparation and detection
  - **E** quantization



eEDM limits over time

Imperial College London



60 years of measuring

zero

Credit: Ben Sauer

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