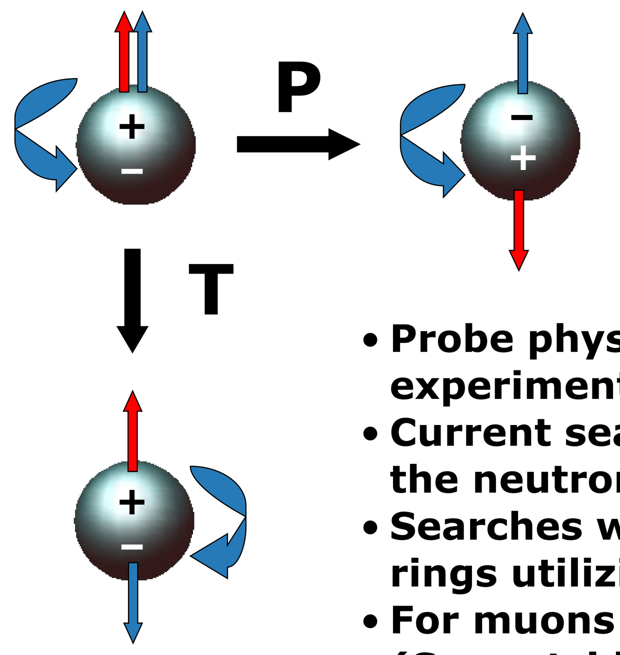
Search for the μEDM using a compact storage ring

A. Adelmann[1], K. Kirch[1], C.J.G. Onderwater[2], T. Schietinger[1], A. Streun[1]

[1] Paul Scherrer Institut, PSI — [2] Rijksuniversiteit Groningen, NL

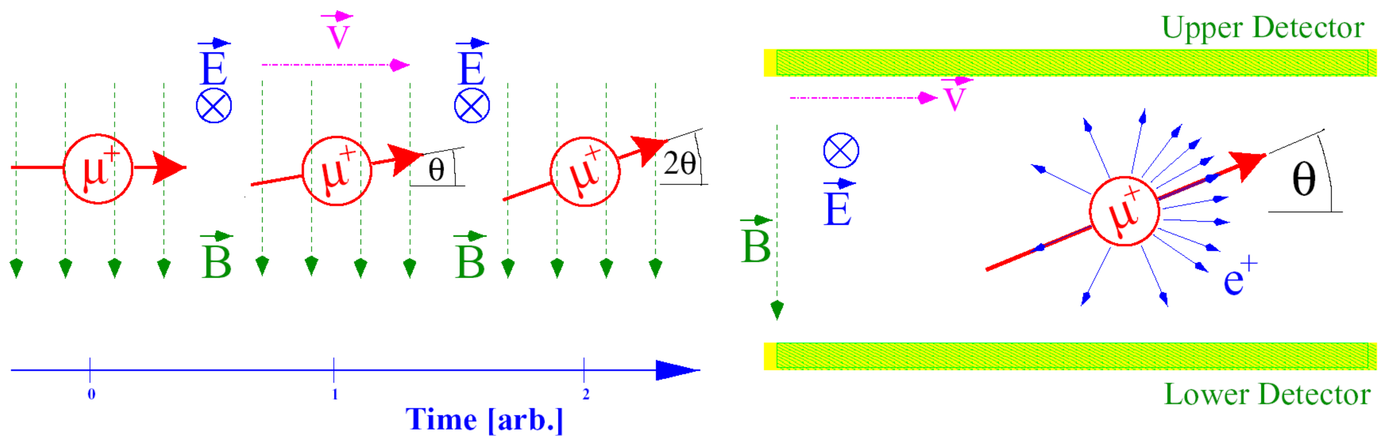
Permanent electric dipole moments (EDM)



- Violate P and T symmetries (Ramsey [1950,1958])
- Violate CP if CPT is unbroken
- Could help to understand the baryon asymmetry of our universe (Sakharov [1967])
- Probe physics inaccessible or complementary to experiments at the high energy frontier
- Current searches mainly focus on neutral probes such as the neutron or atoms
- Searches with charged particles are possible with storage rings utilizing the relativistic v x B electric field
- For muons the frozen spin technique is most promising (Semertzidis et al. [2000], Farley et al. [2004])

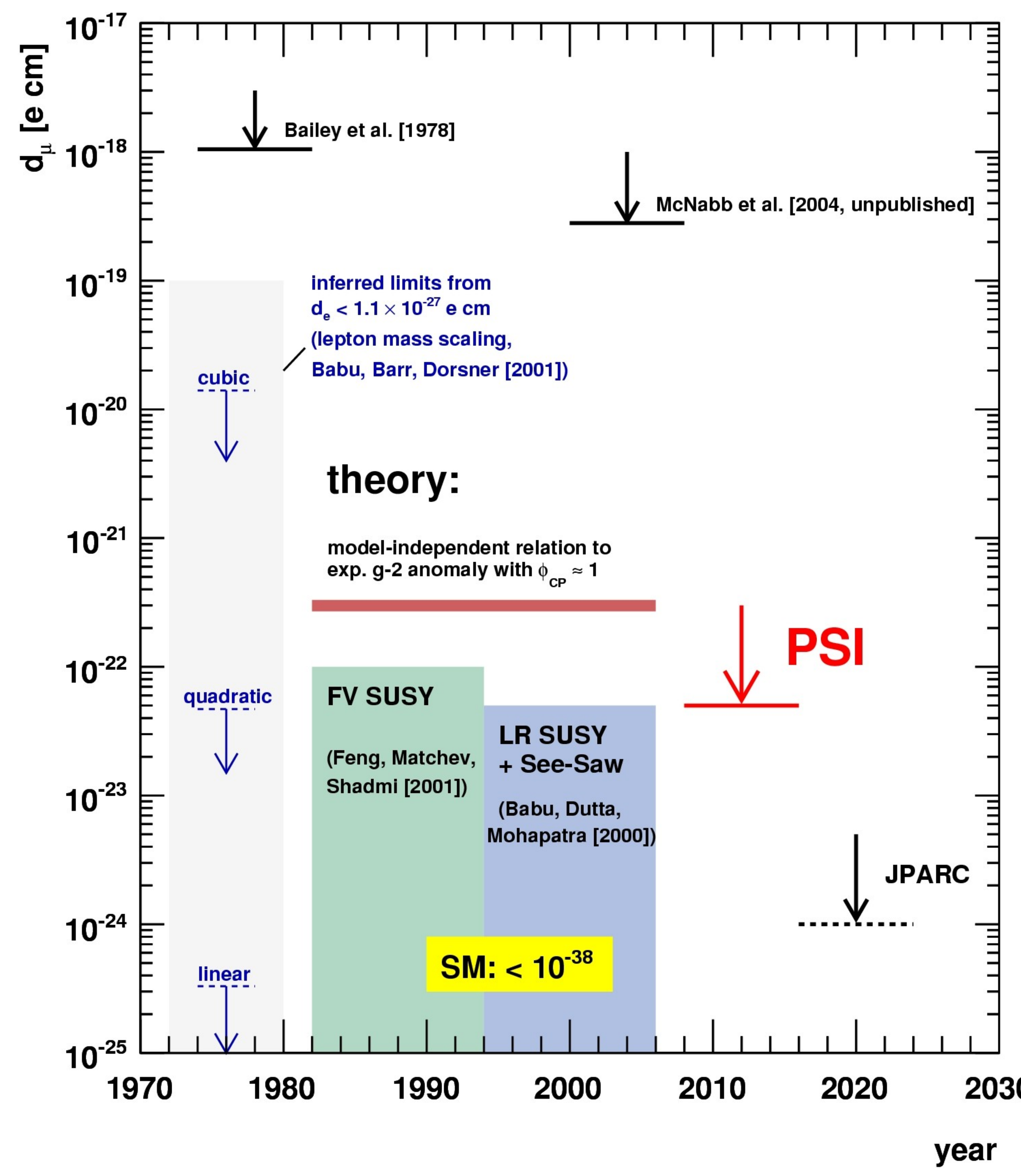
The frozen spin technique

- Longitudinally polarized muons orbiting in a storage ring usually experience a (g-2) precession
- The (g-2) precession can be cancelled applying a radial electric field to freeze the spin (Farley et al. [2004])
- An EDM would precess around the strong v x B electric field and lead to an up-down-asymmetry growing with time
- Proposed for muons at JPARC (Aoki et al. [2003])

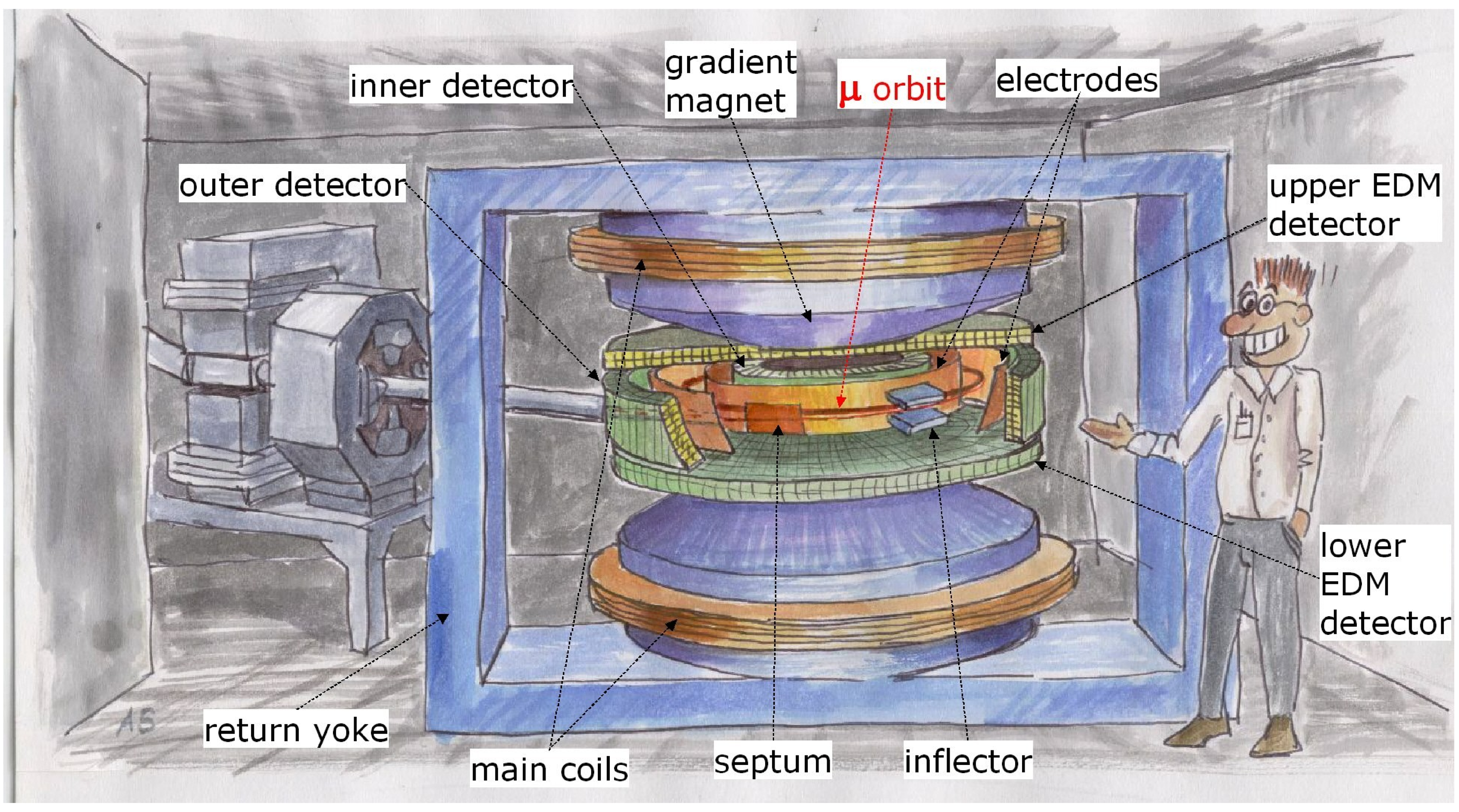


μEDM: experimental reach vs. theory

An experiment at PSI could
·advance the search by 3–4 orders of magnitude in sensitivity
·furnish the proof of principle of the frozen spin method



Concept for a μEDM experiment at PSI



- Trade off high intensity of muon beam for beam quality selecting the muons to be injected into the ring
- Use one muon at a time from the PSI μE1 beam with p_μ=125 MeV/*c* (β=0.77, γ=1.55, P_μ~0.9)
- possible layout: 1 T B-field ⇒ 42 cm orbit radius and 64 kV/10 cm E-field
- Clockwise and counter-clockwise operation (systematics)

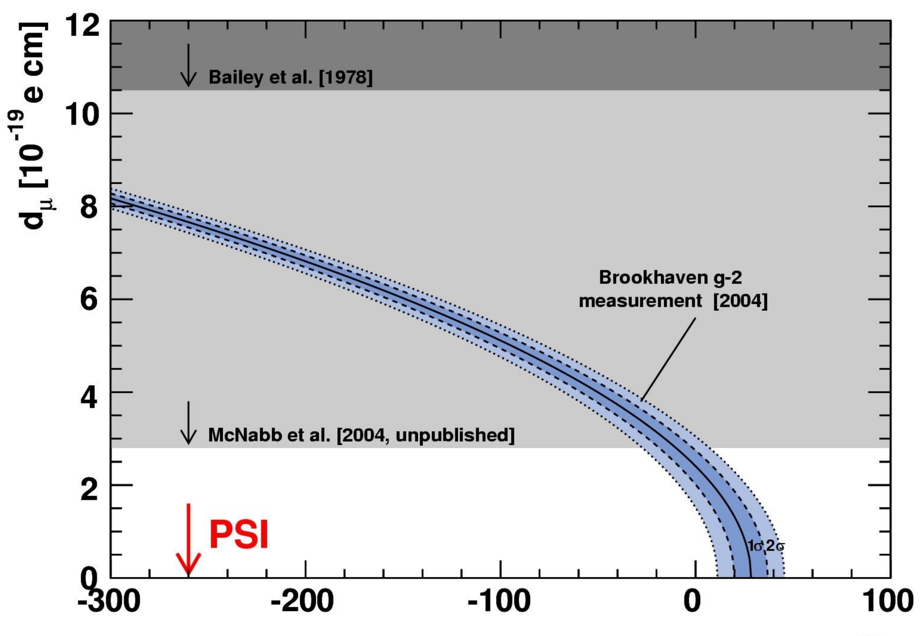
Sensitivity estimate:

- Detect *N* = 5.8 x 10^{12} muon decays per year
- Statistical sensitivity is 10^{-16} *e* cm $/\sqrt{N}$
- Sensitivity after one year:

5 x 10^{-23} *e* cm

New physics in muon g-2?

- The anomalous muon spin precession measured in Brookhaven is usually attributed to new physics in the muon's magnetic moment: a_μ^{NP} = (28.5±8.6)x10^{-10}
- But it could just as well arise from new physics in the muon's electric moment: d_μ = (2.4±0.4)x10^{-19} *e* cm, or a combination of both (Feng et al. [2001])
- Current limits are insufficient to resolve the ambiguity



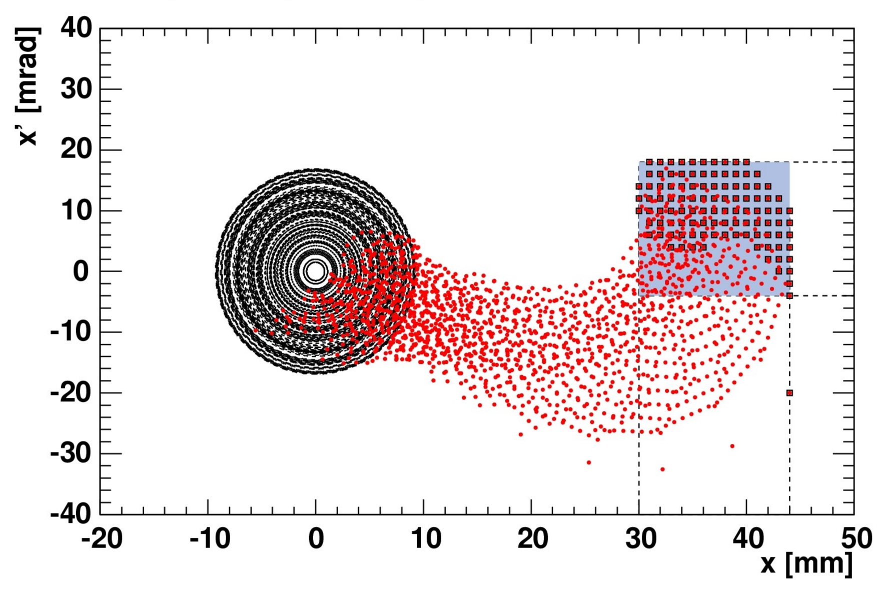
The PSI measurement would definitely confirm or rule out the EDM anomaly!

Ring injection study

- Resonance injection at half-integer
- 20 turns ramp of non-linear inflector
- Acceptance ±7 mm/±11 mrad ⇒ average latency for acceptable μ ~1.2 μs
- Average measurement time ~$\gamma\tau_\mu$ = 3.4 μs ⇒ ~200 kHz repetition rate

Challenges

- Fast identification of acceptable μ
- High irregular rep. rate of inflector



Injection phase space diagram showing collimated muon phase space (blue area), 20-turn injection (red points) and observation phase (black points)

Detection system

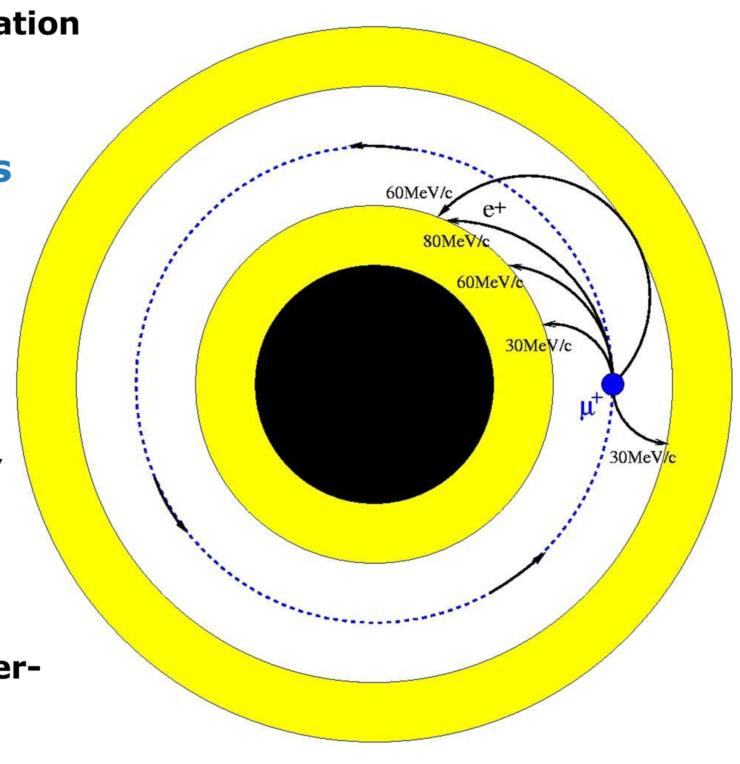
- Identifies direction of decay e± (at least up- or downwards)
- Energy resolution helps (at least low energy cutoff)
- Full reconstruction nice but probably not necessary (at least segments in θ, ϕ, z)
- Timing below 1 ns desirable (at least 10 ns)
- Full GEANT4 simulation in preparation

Systematics issues

- Vertical E-field component ($E_{||}$ / E_{rad} < 10^{-4})
- Rotational mis-alignments and residual g-2 prec.
- Instabilities of B, E, or detector

⇒ Checks

- μ± injection
- Clockwise/counter-clockwise
- Spin rotation?
- g-2 precession / E-field



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